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I. THE POLE STAR AND THE POINTERS.

By Lieut.-Colonel A. W. Drayson, R.A., F.R.A.S.

NEARLY every educated person is sufficiently acquainted with the familiar objects in the heavens to be able to recognise the constellation known as the "great bear." Two stars of this constellation are termed "the pointers," because they point towards a third star called the "pole star." The great bear, the pointers, and the pole star may therefore be called well-known objects; for as these stars always remain above the horizon in our latitude, they may be seen every clear night throughout the year.

Among the hundreds of thousands of persons who look at the pole star and the pointers, probably a hundred times a year, we have hitherto found only about four who have remarked a singular and interesting fact connected with these objects. When, however, we have pointed out the interesting fact, then many persons have asserted that they had noticed the peculiarity we referred to, but that want of confidence in their own observational powers had caused them to conclude that what they fancied they saw was an optical delusion, and not an actual fact. Results, however, of a valuable kind emanate from the peculiarity we shall here refer to; and though in the present article we are compelled to treat the subject in a somewhat popular or superficial manner, it is yet connected with problems of considerable difficulty and of great practical utility, which have hitherto to a considerable extent escaped notice, in consequence of the science of Geometry having in modern times been greatly neglected.

Many years ago it was our fate to make a voyage from England towards the Southern Hemisphere; it was part of our duty to keep what are called "watches" on board ship. We had sometimes to remain on deck from 8 o'clock P.M. till midnight, and at other times from 4 A.M. till 8 A.M., and during these hours we had every opportunity of observing the changes in various celestial bodies, due to the half rotation of the earth, which had occurred from 8 P.M. to 8 A.M.

The pole star and the pointers particularly attracted our attention, for we could easily perceive how the pole star appeared to sink nearer and nearer to the horizon as we passed each day two or three degrees nearer the equator, and we realised one of the first elementary laws of Astronomy, viz., that the altitude of the pole above the northern horizon was always equal to the latitude of the place from which the pole was seen. In 52° N. latitude the altitude of the pole was therefore 52°, whilst in N. latitude 40° the altitude of the pole is only 40°, and so on.

Whilst observing the pole star and the pointers, at intervals of about twelve hours, and when consequently the pointers were at one time east of the pole star and at other times west of it, we noticed that at one time, and under one condition, the pointers appeared to point more directly towards the pole star than they did at other times. When this peculiarity was at first noticed we believed it was in consequence of our want of observation; for we naturally argued that, as the fixed stars did not alter their relative position as regards each other, it must follow that if the pointers pointed towards the pole star at one time, they must do so with equal exactitude at another time. To imagine that the mere rotation of the earth on its axis could cause any alteration in the relative position of three stars in the heavens seemed almost an absurdity, and although night after night, and morning after morning, we observed that it really appeared as if the pointers did point in a variable manner as regards the pole star, yet the fact was passed over—as facts too often are—by those who cannot account for them.

It was several years after our first notice of the pole star and the pointers that our attention was again directed to these celestial bodies, and we once more noticed the same facts as those already referred to, and very shortly recognised the law or cause which produced the appearance, and found how more than one interesting problem depended thereon.

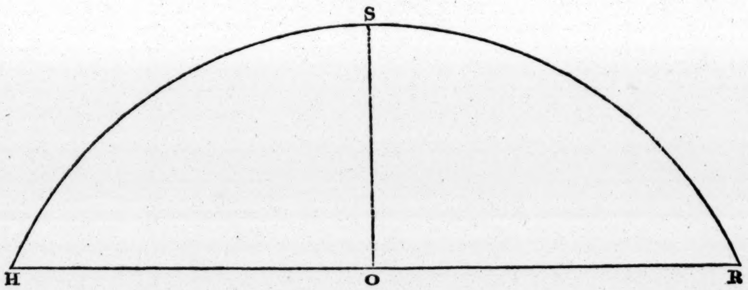
In order that the whole of the problems resulting from the above law should be thoroughly understood, the reader ought to be acquainted with what we may term the geometry of the sphere, and also the various terms used in Astronomy, but to *comprehend* these problems will require but average intelligence, a careful perusal of the following pages, and a sufficient amount of imagination to picture, as it were, on the sphere of the heavens lines that of course cannot be drawn there.

The first problem that we shall submit to the reader refers to the apparent course of the sun in the heavens, from its rising to its setting on the 21st of March.

We will suppose that a person is situated at a locality in 52° north latitude, and facing the south. At 6 o'clock in the morning on the 21st of March the sun would rise above the eastern point of the horizon, trace a curve or arch in the heavens, until at the south it would attain an elevation above the horizon of 38°. When exactly south the sun would move nearly horizontally for a short part of its course; it would then gradually descend, slowly at first, but more rapidly afterwards, and at 6 o'clock P.M. would set below the western point of the horizon.

If we could mark out on the heavens the course traced by the sun, as stated above, we should draw a curve similar to H S R in the annexed diagram. In this diagram the horizon is represented by the straight line H O R, H being the east, O the south, and R the west points on the horizon. S would be the position of the sun relative to H O R when the sun was south, and the arc O S, representing the sun's altitude, would be 38°.

FIG. 1.



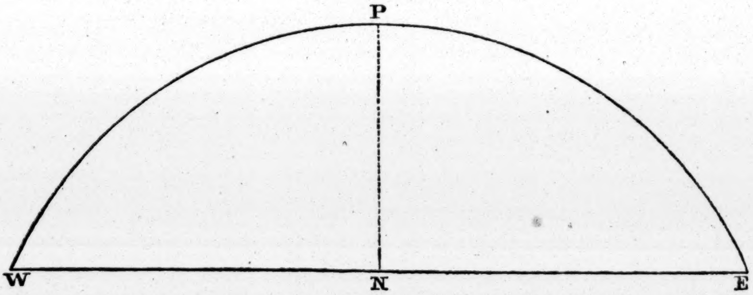
It will be seen that, if we could sketch or mark on the sky the course traced by the sun, this course would appear to us a great arch, as shown by H S R.

Now this arch traced by the sun on the 21st of March is the position which the earth's equator would occupy if produced to the distant sky, and this arch is termed the equinoctial. The equinoctial therefore cuts the east and west points of the horizon, traces a curve in the heavens, and at its south point is as many degrees above the horizon as 90° exceeds the latitude of the place of observation.

We will now suppose that the observer turns round and faces the north, and traces out on the sky the half of a great circle which cuts the east and west points of the horizon, and passes through the pole of the heavens. This circle the reader, on reflection, will perceive must be a circle at right angles to the equinoctial, and its trace in the sky would be as follows:—Starting from the east point of the horizon, this circle would trace an arch in the heavens the highest part of which would be at the pole, when its altitude above the horizon would be equal in degrees and minutes to the latitude of the place of observation; the curve would continue its arch-like form, and would cut the western point of the horizon. This curve or arch traced in the sky by a great circle passing through the pole, and cutting the east and west parts of the horizon, would appear as shown in the following diagram.

In this diagram N represents the north portion of the horizon, P the pole of the heavens, E the east and W the west points on the horizon, whilst the curve E P W shows the curve or arch traced by a great circle in the sky, which great circle is at right angles to the equinoctial, and cuts the east and west portions of the horizon.

FIG. 2.



The reader may perhaps wonder what these arches have to do with the pole star and the pointers: they have everything to do with them, and in fact are the key to this and to other mysterious problems which seem to have hitherto greatly perplexed some persons, for both this and the preceding arch are in reality straight lines, though they *appear* as curves to us; for both this curve and the arch traced by the equinoctial would appear like straight lines to a person at the north pole of the earth, the equinoctial there appearing coincident with the horizon, and therefore like a straight line, the curve E P W appearing like a vertical line and as straight as a plumb-line.

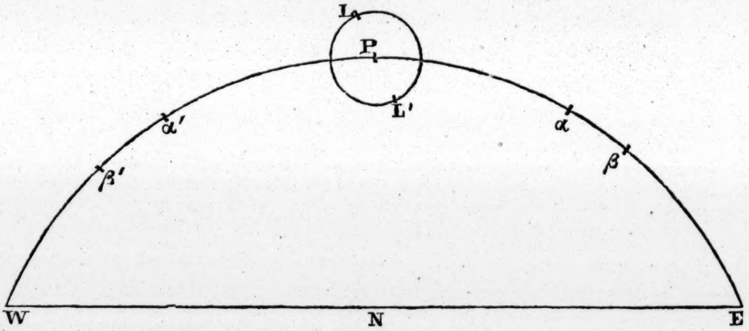
We will now place relatively to the curved line W P E three stars, and show what would be the relative changes in twelve hours of these three stars, and due merely to the rotation of the earth on its axis.

W N E represents, as before, the horizon; the curved line P E a portion of the great circle, at right angles to the equinoctial, and cutting the east point on the horizon. P represents the pole of the heavens, and P W the remaining portion of the great circle that is above the horizon.

On the arc of the circle P E we represent two stars, α and β. A *straight* line joining these two stars, and produced in the direction of the pole, would reach a point L. We will suppose a star situated at L on the meridian, and above the pole.

Under the conditions given above the stars β and α point with great exactitude towards L, because an apparently straight line joining β and α, and produced, would pass through L.

FIG. 3.



In consequence of the rotation of the earth on its axis the star at L and above the pole would in twelve hours be carried round the true pole, P, and would trace a semicircle, and reach the point L′ *below* the pole, the arc P L being equal to P L′. Due to the same cause the stars α and β would appear to trace semicircles round P, and would occupy, in twelve hours from the time at which they were at α and β, the positions shown by α' and β'.

A line joining α' and β', and produced towards the pole, would now reach the point L, as before, but the star which was at L is now at L′, *below* the pole. Consequently the two stars α' and β' do not now point towards the same star at which they pointed when they were in the positions shown by α and β.

In order to illustrate the problem we have selected three stars in such a relative position as to show the effects in a prominent manner, and it happens that the actual position of the pole star and the pointers is not so very different from that of the three stars given above. We will now map out, as it were, the pole star and the pointers according to their true position relative to one another, and as seen by an observer in N. latitude 52°, at various times.

The pole star is not situated exactly at the pole of the heavens, but is distant about 1° 27′ from the true pole, and therefore describes every twenty-four hours a circle round the pole, the radius of which circle is about 1° 27′,—that is, nearly three times the apparent angular diameter of the sun, for the diameter of the sun subtends an angle of about 32′.

The pointer nearest the pole is about 27° 34′ from the pole, whilst the second pointer is about 32° 49′ from the pole. These two stars during every twenty-four hours appear to trace circles in the heavens round the pole of the heavens, the radius of each circle being 27° 34′ and 32° 49′.

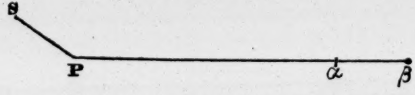
We will next refer to the lateral divergence of these three stars from what we may term a straight line, and in order to do this we must refer to what is called "*Right Ascension;*" a term which probably some readers may not be acquainted with, but we will give such a popular description thereof as shall render the explanation intelligible to any person.

The right ascension of the pole star is about one hour and twelve minutes, which converted into degrees is 18°. The right ascension of the nearest of the pointers, viz., *α* Ursæ Majoris, is ten hours fifty-five minutes, whilst the second pointer *β* Ursæ Majoris has a right ascension of ten hours fifty-three minutes. Converting these differences of right ascension into degrees it follows that the difference in right ascension between the pole star and the pointers is, in round numbers, 145° 43′.

Let us now explain this fact in more popular language.

If in the following diagram P represent the pole of the heavens, S the position of the pole star distant 1° 27′ from P, *α* and *β* the two pointers, then the angle S P *α* will be 145° 43′.

FIG. 4.

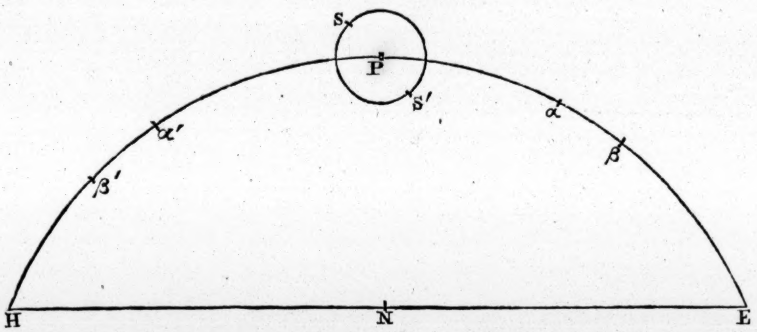


Now the point P always remains fixed in the heavens, and whilst S revolves round P, and *α* and *β* also revolve round P, yet the angle S P *α* will always remain a constant in value, and will always be 145° 43′.

We can now trace out the changes which occur in the *apparent* relative positions of the pointers and the pole star under certain conditions, and we will first describe these when the pointers are east of the pole star.

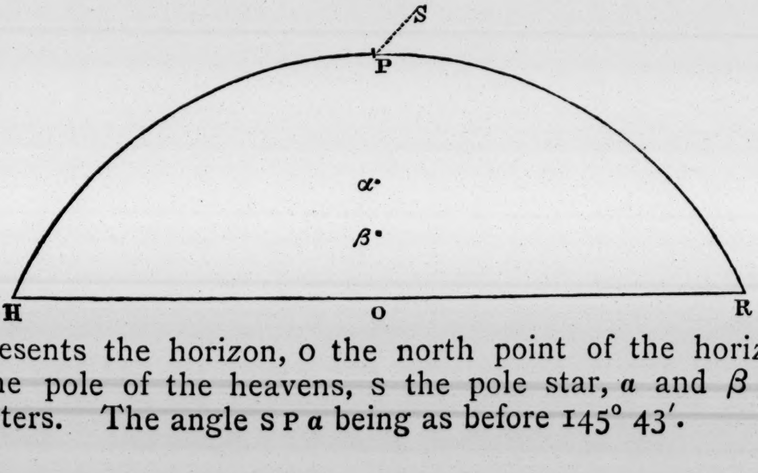
In the following diagram P represents the pole, S the pole star, *α* and *β* the pointers, H N E the horizon, E the east, N the north, and H the west points. Under these conditions the pointers point with tolerable exactitude towards the pole star. When twelve hours have elapsed the pole star will be seen at S′ in its circle, the stars *α* and *β* will appear in the positions *α*′, *β*′, and it is now evident that these two stars do not point at the pole star, although as before the angle S′ P *α*′ is 145° 43′.

FIG. 5.



In six hours after the stars *α*′ and *β*′ were in the position shown in the last diagram they would be on the meridian and below the pole, and as these two stars differ only two minutes in right ascension they would, when on the meridian and below the pole, point almost vertically upwards. The pole star, however, would now be 90° in its circle from S′ in the last diagram, consequently the pole star and the pointers would as regards each other then occupy the relative positions shown in the following diagram, where H O R represents the horizon, O the north point of the horizon, P the pole of the heavens, S the pole star, *α* and *β* the pointers. The angle S P *α* being as before 145° 43′.

FIG. 6.



It is evident that under the above conditions the pole star is not pointed at directly by the pointers, nor will it be until the stars α and β ascend to the east and reach nearly the same altitude as the pole star.

It will be evident from the preceding demonstrations that the pointers point with the least exactitude towards the pole star when then they are west of that star and on the great circle nearly at right angles to the meridian. It may appear somewhat singular to many readers when we state that this *appearance* (for it is but an appearance) will hold good for our latitudes, but it would not occur to a person who might be situated at the North Pole. Such a statement may seem incorrect, but it is a truth, the reason for which may be understood by the following description:—

To a person situated at the North Pole every star in the heavens would appear to trace a circle during twenty-four hours round a point exactly over his head. Every star, therefore, would appear to move parallel to the horizon. If these four or five stars were arranged in a straight line from the horizon up towards the zenith, these four or five stars would always appear to an observer at the pole to lie in the same straight line. The curve or arch joining P and R in the last diagram would appear to an observer at the pole a *straight* line rising from the horizon directly to the point over his head, and not a curve or arch, as it appears to a person in such a latitude as 52°.

Here, then, we have the key to the peculiar fact that the pointers do not always appear to us to point with equal accuracy towards the pole star. It is because owing to what we may term the peculiar perspective of the sphere of the heavens that which appears under one condition as a straight line may appear under another condition as a curved line, and as the pointers are on the apparent sphere of the heavens, and alter their relative positions as regards the horizon, the effects are such as we have stated them to be.

In order to render this problem as intelligible as it should be, we will again refer to the course or trace of the equinoctial on the sphere of the heavens, and described in an early page of this article. We pointed out that the equinoctial, if it could be marked out on the sphere of the heavens, would be represented by a great arch which cut the east and west points of the horizon, and attained an altitude at the south equal to 90° less the latitude of the place of observation. This curve would remain constantly marked on the sky during any number of rotations. It would be evident to our senses that a line must be a curved line which could be drawn on the sky commencing from the east part of the horizon, rising rapidly at first as an arch does rise, then as the equinoctial approached the south the arch would be traced nearly horizontally, then it would slowly descend, afterwards more rapidly, and finally cut the west point of the horizon. Therefore every portion of this equinoctial would appear a portion of a curve, and it could not be considered a straight line any more than a rainbow appears a straight line.

What shall we say, however, when we trace out the equinoctial on the sky as it would appear to a person at the North Pole?

To an observer at the North Pole the terms east and west do not exist. The south is beneath his feet, the north exactly over his head, and the east and west undefined. To him the equinoctial would not rise above his horizon as it would to an observer in middle latitudes, but the equinoctial would *coincide* with his horizon in all directions.

To every person who may be on the same level as the sea, and when a clear defined sea outline is visible, the horizon appears like a *straight* line, and all parts of the horizon appear like portions of a straight line: therefore to an observer at the Pole the equinoctial will appear like a straight line, and will be coincident with the horizon, yet to an observer in middle latitudes the equinoctial will always appear as an arch in the heavens.

The same geometrical or optical laws which cause the equinoctial to appear a straight or a curved line, according as the observer is in one part or another part of the earth, also cause the pointers to appear under certain conditions to point exactly towards the pole star, whilst under other conditions they will not appear to point with equal accuracy to the same object.

The same laws produce other effects in connection with certain celestial bodies, some of which effects are so palpable as to attract the attention of every observer, whilst other phenomena are noticed (spontaneously as we may term it) only by those who possess good observational powers. When, however, the peculiar facts are pointed out, and the celestial objects themselves illustrate the problem, few persons are incapable of perceiving the paradox, and the majority are anxious to learn the causes which produced it.

In the present article we have confined our description to the pole star and the pointers, but on a future occasion we purpose treating two other phenomena even more easily observed than is the fact connected with the pointers; yet these others have long remained mysteries to certain individuals.

The reader who has read and mastered the preceding problem may amuse himself by testing the observational power of his friends. He may enquire whether his friend has ever remarked the pole star and the pointers. Then he should carefully word his next question somewhat in the following terms:—"Of course the pointers always point with equal accuracy towards the pole star," and in the majority of cases he will obtain for his answer, "Of course they must do so, as the stars never alter their relative positions from each other." If the reader, instead of the above careful question, were to say, "Have you ever remarked that the pointers do not always point with equal accuracy to the pole star," he would in many cases receive some such answer as the following:—"Well, I fancy I have noticed it, but I am not very sure about it."

So rarely do we find any but the most candid and progressive, who are willing to acknowledge their ignorance of a subject, that the above problem may afford those who have thoroughly mastered it considerable amusement and some information when they cross-examine those among their acquaintances who profess to have a knowledge of astronomy.

II. PEAT BOGS.

By G. H. Kinahan, M.R.I.A., &c.

THE formation or growth of peat bogs and that of most, at least, of our principal coal seams, were evidently very similar: it is therefore interesting to be acquainted with what may be ascertained about the former.

Why peat bogs began to grow at first is a question often asked, but as yet not satisfactorily answered. In Great Britain and Ireland there are three classes of peat, distinguished by three modes of occurrence, namely, *first*, the preglacial or intraglacial peat; *second*, submarine peat; and *third*, the subaërial, or the peat accumulations that are still being formed. The latter, however, as will hereafter be mentioned, can in certain places be subdivided, as there is proof of a long cessation of peat growth having intervened over vast areas during its period of formation. In this paper the facts witnessed in Ireland will be those chiefly considered, but at the same time some reference will be made to places in Scotland or England as they show the similarity of the growth of peat in the three countries.

There does not appear to be in Ireland any peat accumulations under the undoubted normal boulder-clay-drift. Near Nenagh, Co. Tipperary, there is a black peaty bed under "forty-three feet of hard calcareous clay, with numerous lumps of limestone intermixed, but unstratified."* In Boleyneendorrish Valley, near Gort, Co. Galway, there is an argillous peat under about 25 feet of a glacial drift,† and in some of the pits of the Newtown Colliery, Queen's Co., 3 feet of peat was found under 96 feet of drift which was, at least in part, glacial. From this it will be seen that although such peaty accumulations may not have been formed prior to the glacial period, yet that some are evidently intraglacial,—that is, they were formed subsequent to the beginning and prior to the end of the glacial period. There are also fragments of peat found in the marine gravels in the country west of the south portion of Lough Corrib, Co. Galway. These gravels, when compared with the gravels of the "Esker Sea period" of the central plain of Ireland, seem to be evidently recent; still they appear to have been formed before the final disappearance of the ice from the neighbouring highlands, as ice-carried erratics are occasionally found lying upon them. In the peaty accumulations of Boleyneendorrish, Dr. Melville, of the Queen's University and Queen's College, Galway, detected numerous cones of the *Pinus sylvestris*, cones of the *Abies excelsa*, De C., fragments of wood (chiefly coniferous), portions of branches, scales of bark, pieces of fir bark, an imperfect hazel nut, and leaves of plants, which prove the presence of such trees on the western portion of the British Islands during at least the latter portion of glacial times.

Submarine peat is not uncommon off the coast of Ireland, and in many of the estuaries and brackish water lagoons. In the east of Ireland, at the present time, there is very little peat growing on the lowlands, yet off the coast, and in the estuaries, &c., submerged bogs are not uncommon. They have been proved to occur from high-water mark to a depth of 20 or 30 feet; those under the estuary muds of Wexford Harbour having been found to a depth of 20 feet below the surface of the mud, or about 23 or 24 feet below mean high-water mark: these bogs are found to contain the roots and trunks of oak, yew, deal, hazel, sallow, and a timber like ash, also hazel nuts. In the south and west of Ireland lowland bogs are numerous, and it is a common occurrence to find—off a coast where bogs now form the sea margin—peat from 8 to 12 feet deep, even at low water of spring tides, giving a depth below mean high-water mark of from 23 to 25 feet. In these bogs the roots and trunks of oak, yew, deal, willow, and hazel are found, similar to the tree remains that occur in the inland bogs. Off the south-east coast of England there are also submarine bogs; those in Romney Marsh and Pevensey Level being at nearly similar depths below the mean high-water mark. It has been suggested that the peat accumulations found in lagoons, estuaries, and even on the open coast, may have grown at their present levels, the sea being kept out from them by a barrier of sand, gravel, or the like, which was subsequently swept away or moved inland. If, however, we consider a moment, the erroneousness of such an idea is apparent. Take, for instance, such places as Romney Marsh in England, or Wexford Estuary in Ireland, where we find the roots of oak *in situ* more than 15 feet below the mean low-water mark. These trees, at the time they were growing, would have been liable at any time to have been inundated, while even at low water of spring tides they would have had no drainage. Such trees as the willow and alder might possibly grow under these conditions; but such trees as the oak, yew, fir, ash, and hazel require a drainage from the ground on which they grow; these, then, never could grow and arrive at maturity on ground below low-water mark. Such bogs, therefore, as those in which the remains of the last-mentioned trees are found, must have been while the trees were growing above high-water mark. Moreover, the process of subsidence would seem to have been gradual, to allow the peat-forming plants time to grow and decay in oft-repeated succession.

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* Paper by T. OLDHAM, M.R.I.A., Journ. Geol. Soc. Dubl., vol. iii., p. 64.

† Mem. Geol. Survey, *ex* Sheets 115 and 116, p. 28.

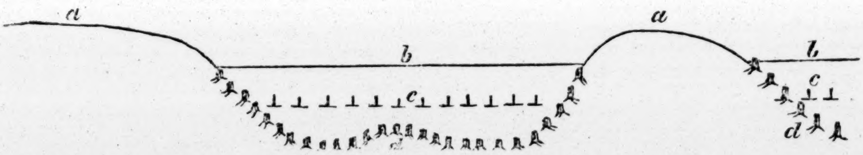
The plant-remains in the submarine peat are, as a general rule, similar to those found in the subaërial lowland or "red bogs," and we may reasonably conclude that the peat accumulated under very similar conditions,—that is, as a "red bog," and not in a lagoon or marsh. It also must have taken a very long time to accumulate, as peat when drained will contract more than half its height, while if weighted and compressed—as the peat under estuary mud—it would be reduced a third or fourth more, so that the 5 feet of peat under the muds of Wexford Estuary would represent a growing bog of from 15 to 20 feet in depth.

The normal lowland or "red bogs" of the central plain of Ireland are very similarly circumstanced to the ordinary coal seams, having an under-clay which is more or less penetrated by the roots of the trees and larger plants which at the first occupied the land. In most of them, as also in many other low-lying bogs, the roots and the trunks of the trees under the peat, or in the lowest strata, are principally those of oak and yew, as if prior to the growth of the peat the low country was for the most part a vast forest of these kinds of trees, the oak greatly preponderating. In these forests mosses and other peat-producing plants began to grow and flourish, till eventually they stopped the drainage, and formed an envelope of peat which gradually killed the trees, while subsequently the stems rotted off, between wind and water, the trunks toppling over and being entombed by the succeeding growth of the peat. After the disappearance of the major portion of the oak forest, the bogs for years gradually increased in depth, till suddenly—from some as yet unexplained cause—their growth ceased, and on their surfaces forests of deal sprang up. During all this time, however, portions of the original oak forest were preserved, and some of them apparently remain in certain places to the present day. This seems to have been due to the oaks and associated trees being destroyed only in those comparatively level places in which the peat could easily accumulate. On hills that were above the general level of the peat the oak would still flourish, and during the "Deal Forest Age" each of these hillocks remained an oak grove. At the present day, in many parts of Ireland, the hills and exposures of drift in a flat bog are called "*derries*" (*Anglicè*, oak-woods), the ancient name, which has survived down to the present age from the time when they were oak groves surrounded by forests of deal. Still this name may be more modern, as it is probable that, even after the deal forests disappeared, many of these hills still remained oak-woods. The derries in the midland counties of Ireland have long since been cleared of their timber, and are now under tillage or grass land, but in a few places—such as some of the wild tracts in Mayo—the oak may still be found growing on the drift islands in the bogs, it always being associated with yew, hazel, birch, ash, and holly; probably the last three trees were also denizens of the primary forests, but their timber has long since disappeared, they being of kinds that rot quickly in bog.

That such was the mode of the growth of the bogs is proved by the different sections exposed, as beneath the peat in the clay, marl, or gravel, are found the "corkers," or roots of the oak and yew, following the undulations of the ground, while above them—in horizontal layers, and separated from them by from about 4 to 10 or 12 feet of peat—are the roots of the deal forest, which at the sides of the hills join the oak roots, as shown in the accompanying sketch section. In a few lowland bogs, however, and in many bogs in the mountainous districts, the lower and upper systems of corkers will belong to deal trees, as if in such places there had been two distinct ages of deal forests.

Some of the lowland or red bogs are of great depth, in a few places up even to 50 feet, but on an average they generally do not exceed 20 or 30 feet, and often are much less. A typical red bog gives four kinds of peat: near the surface is a clearing of more or less living organic matter, from 3 to 6 feet in thickness; under this is *white turf*, then *brown turf*, and lowest of all *black* or *stone turf*. White turf is a nearly pure organic substance, very light when dried, burns quickly, giving out only a little heat, and leaves little or no ash.

FIG. 7.



a. Drift Hills or Derries. *b.* Surface of bog. *c.* Deal corkers. *d.* Oak corkers on gravel.

Brown turf is always more or less mineralised. Black or stone turf is a chemico-organic production, and may contain such minerals as pyrite or marcasite; often it is semicrystalline and seems to pass into *lignyte*, and when burnt it always leaves more or less ash. A variety in many bogs is locally called "Monagay" turf, which is very brittle, and full of the fragments and stems of flagger-like plants. Under monagay turf marl always is found, while under typical black turf there is usually gravel, suggesting that the monagay turf accumulated in a marsh. Another variety, always found at the very bottom of a bog when cut, is of a pale greenish-yellow colour: this, if allowed to dry, fully "melts" or disintegrates under the atmosphere, but if stacked when half dry it becomes a beautiful, hard, compact turf, that burns with a strong heat and brilliant light.

The residue or ash of peat generally, but not always, is greater the more deeply the peat is seated. In some places mineral matter may be carried up into the peat from springs and the like; but the ash of peat seems usually due to the plants growing on the surface collecting their inorganic food from the atmosphere, and after their decay to the collected mineral substances being continually carried downwards by the water percolating through the mass: in this way each lower portion becomes more impregnated than the parts above it, and when burnt its ash or residue is greater.

The bogs on mountains are vastly different from those on the low lands. The latter usually grow on more or less flat places, where the substratum is non-porous, on which they form extensive level plains, while in the mountainous districts bog may grow anywhere on the hill-tops, as well as in the valleys, and from the latter they creep up the slopes over porous and non-porous strata. They are generally of small depth as compared with the lowland bogs, as here the peat grows much more slowly and more densely. In typical mountain bogs the *clearing*, or partly living organic matter, rarely exceeds 12 inches in depth, and this lies on *brown turf*, under which there may be *black turf*, but not always, as in some places the peat envelope is too thin to form the latter by compression. The difference between mountain and lowland peat is evidently due to the different rate of growth of the peat-producing plants in the respective positions. In the low flat land the growth of the plants is more rapid than among or on the mountains; consequently while on the former a light spongy substance is accumulating, on the latter a heavy felt-like mass is being formed. Besides, in all mountainous districts portions of the peat are very much subject to denudation by rain, runlets, and wind, which carry particles of peat from one place to another, and, by depositing them on the surface of the growing peat, keep the surface even, and make the peat compact and firm. In this way, on the growing peat may be deposited a layer of derivate or sedimentary peat, which will afterwards become interstratified by a subsequent growth of the plants. In flat mountain bogs, and also in the lowland bogs, when the latter are situated at the base of a hill or along a river subject at times to extensive floods, layers of sand, gravel, silt, or the like, may be found in the peat, such foreign material having been deposited on the surface of the bog during freshets, while afterwards the peat grows over them.

In coal-mining we find parts of seams absent; such deficiencies are called "faults," "troubles," "horses," &c., by the colliers, and the formations of these coal-less portions of a vein are explained by the study of some peat bogs; as we find the mass of the peat in some places denuded by the wind, and in others by a stream, which cut into it and break its continuity, and if, after this, the bog were to be covered up by newer strata, such vacancies would be filled with foreign materials similar to the "troubles" or "horses" in a coal seam.

In the mountain bogs of the British islands the prevailing timber seems to be deal, and some of the sticks are of lengths that the fir rarely attains at the present day in these countries. The absence of the remains of the oak in the highlands of these islands would seem to suggest that the oak could not flourish above a certain altitude, which in Ireland seems to have been about the 400 feet contour line. This would seem to suggest that prior to the age of the first growth of the subaërial peat the lowlands, and the hill-sides to a certain height, were covered with oak forest, while above that height, the hills grew deal, the deal trees then flourishing at much greater altitudes than now, as large sticks are sometimes found in bogs at heights of above 1000 and 1200 feet.

From the above we may regard it as probable that there has been, since the glacial period at least, two ages of the most active growth of peat—*first*, after the great oak forest period, and *second*, subsequent to the deal forest period. That a considerable break occurred between them is evident, but the cause of it is unknown. There may indeed have been a third period, while the now submarine bogs were growing: this, however, does not appear probable, for at the present day the lowland bogs may grow at any height from high-water mark to the 200 or 250 contour line: it is therefore possible that the submarine bogs were forming at the same time as the lower strata of our present subaërial bogs, although now found under such different conditions. The turf-cutters on the sea shore generally tell you that "the turf is of the same depth at high- and low-water mark," but they cannot say if the corkers or roots of the trees stand perpendicular. If they are correct it would necessitate that seaward the peat has sunk more than at the shore-line. On a straight shore-line this might be possible, but on the indented coasts of our bays it is highly improbable.*

In studying bogs, one of the greatest difficulties is to procure reliable data by which to be enabled to estimate the rate at which they grow. Undrained bogs grow; drained bogs, as long as the drains are effective, will not; and it would appear, from the Irish annals, that both before and since the English occupation attempts were made to drain and reclaim the lowland bogs, while they were again allowed to run wild in subsequent troublous times. These artificial stoppages of the growth of the peat have complicated matters, as respects some bogs, so that it is now impossible even to guess how long they may have been growing. At the present day the growth of the lowland bogs in Ireland is generally small, on account of their being more or less drained, and from turf being cut round their margins. In places, however, where the drainage has been for a long time neglected, a perceptible change in their height will take place: this, however, may in part be due to the bog soaking and swelling with water. A road through a bog will rise if the side drains are allowed to become choked. The margins of others, after the turf-cutting has been abandoned, gradually begin to resume their natural form, and if left long enough the peat will begin to creep out upon the adjoining upland, the growth being sometimes very rapid: certain bog-holes that were abandoned in 1848 are now nearly filled with new peat, but of a very soft spongy nature.

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* Near the shore-line I have seen the corkers standing perpendicular, but I never saw an off-shore hole bottomed, as the incoming tide usually drives away the turf-cutters before they can take out all the turf; and I very much suspect my informants told me what they considered most probable, and not what they actually saw.

In the mountainous districts Nature has been less interfered with, and thus many facts in relation to the growth of bogs, can be advantageously studied. Bogs naturally grow more readily on flats than elsewhere, and among the hills we find the deepest peat on the flat hill-tops and in the flat valleys: it, however, does not confine itself to such places, but creeps up and down the adjoining slopes. The latter process might be expected to be the easiest: this, however, does not appear to be the case, especially if the slope is steep. Bogs on an exposed hill are denuded at the edge during storms, especially if these are accompanied by rain. Such bogs are thus prevented from creeping downward, while the annual growth and decay of the plants increase their thickness, thus forming low long cliffs in all exposed places; it is only in sufficiently sheltered situations that the peat covering extends continuously downwards. But bogs creep rapidly upward, even in places where the slopes are composed of porous materials; as the wind, rain, and runlets will add boggy stuff to its edge, forming rapidly a soil in which heather, moss, and other peat-producing plants rapidly grow. In some of the valleys in the Connemara hills there are coarse shingle slopes, with a covering of peat often as much as 8 feet deep, while the bog on the adjoining flats is not much deeper. This peat originated with peaty matter from the flat tops of the hills, that was lodged on the surface of the stones, by rain and wind, on which heather, &c., grew, and by the growth and decay of such the great thickness of peat was accumulated; from these shingles the peat is extending up the slopes of the hills.

In some of the once-inhabited but now depopulated valleys (and similar facts may be observed in parts of the highlands of Scotland) the growth of the peat is remarkable; it now having nearly obliterated the sites of the farmsteads and fields. The growth of peat differs on the hill-tops and in the valleys: on the first it is somewhat similar to that of lowland bog, in the plain it being principally due to the growth and decay of vegetation; for this reason it is more or less tussocky: but the turf in the valleys is only partially due to vegetable growth and decay, for it is partly derived from peaty matter carried on to it; it is therefore usually much more dense and level on the surface; it is, however, very variable in composition, as in some places it is more favourably situated than in others for receiving extraneous matter.

As yet no human relic has been recorded from the submarine bogs; but as such peat accumulations have only been proved by borings or small excavations, while vast extents are unexplored, it is not likely that they should have been found; but in the subaërial peats they are not uncommon. In Drumkelin bog, parish of Inver, Co. Donegal, a log house was found under 14 feet of bog, the house being 8 feet high, while *under* it was 15 feet of bog, in all 37 feet deep. Stone celts, sharpened stakes, and methers full of lard or butter, have at different times been exhumed from under bog from 10 to 15 feet deep, in the mountain pass N.W. of Glenbonniv, parish of Feakle, Co. Clare; and the late J. Beete Jukes, F.R.S., on seeing the huts, remarked that they were exactly similar to the huts built by the natives of Newfoundland to shelter them while waiting for the deer in their annual migration. In one place in the ridge of hills N.W. of the small market-town of Clifden, Co. Galway, wattle fences were found stuck in the clay under bog from 8 to 12 feet deep. The ridge of these hills is very uneven, large flat spaces occurring, usually connected by more or less narrow passes. These wattle fences consisted of stakes driven into the ground, and interwoven with horizontal rods or branches, gaps here and there being left open; they always occurred opposite to one of the passes leading from one flat to another; and what seems remarkable about them is that they are similar to the description of traps made for deer at the present day in Russia. In the bog close to Castleconnell, Co. Limerick, a mether full of a substance like whey was found standing by an oak corker, and 5 feet above the oak corker was a layer of deal corkers, while a short distance above the horizon of the latter, extending from the edge of the bog next the old castle of the O'Connings to an esker called Goig, was a roadway of oak timber built similarly to an American corderoy, and over the roadway was from 10 to 12 feet of solid peat; alongside the road are said to have been the remains of ancient bog-holes in which the peat was cut in a mode similar to that of the present day. From this bog we learn that the oak forests were inhabited, while subsequently oak timber was accessible in the neighbourhood, probably on Goig, after the destruction—at least in part—of the great pine forests, and that peat fuel was used at a very early age. The finds of stone and other weapons, also of butter or lard, are too numerous to mention, the latter occurring sometimes in lumps without the trace of any envelope,—sometimes in methers, barrels, cloths, and in conical vessels made of hoops and straight sticks, lined with cloth; some of them evidently were purposely buried, while others seem to have been dropped, and subsequently covered by the growth of the peat.

Hitherto we have been occupied with facts; now, however, we will, in part, have to deal with conjectures. The intraglacial peats in the localities that have been enumerated seem to be very ancient; those at Newtown, Queen's Co., and near Nenagh, Co. Tipperary, undoubtedly are so, and after their accumulation must for years have been under an ice-sheet. The peaty stuff in the Boleyneendorrish Valley, Co. Galway, must also have been under ice, but probably at a much later age than the others, and possibly after the ice had left most of the low country, while the pieces of peat in the marine gravels west of Lough Corrib are—comparatively speaking—recent, as the gravels were formed subsequent to the Esker Sea period, and during the time when only the lands under the present 150 feet contour-line were submerged. In a coom that lies on the north side of Mount Leinster, Co. Carlow, there is a peat under drift from a few inches to over 4 feet in depth: this peat, however, has not been previously mentioned, as the drift evidently is not a normal glacial drift, but has been arranged by meteoric action, and was probably washed down from a higher part of the coom.

Since the oak forest age there must have been various changes in the climate of Ireland. Oaks, indeed, would grow at the same altitudes as those at which the corkers are found in the bogs, but then it must be remembered that these places are probably at least 50 feet lower than they were when the oaks flourished; besides, the bog oak occurs in exposed situations in the west of the island, where now no trees of the same dimensions would grow; and deal at the present day cannot be grown at the altitudes or in the situations where large bog deal sticks are found.

The history of the submarine and estuary peats may be as follows:—When the land was about 40 or 50 feet higher than at present, or even more, forests grew; subsequently the drainage became defective, either from the land sinking or from the growth of ferns, mosses, and the like,—probably the latter,—till eventually the forests disappeared, and bogs replaced them. Afterwards the land must have been depressed, and probably in general rapidly, for if the sinking was gradual the upper strata of the bogs would have been formed from the growth and decay of flaggers, reeds, and other marsh plants, while usually the peat seems to have formed from the same class of vegetation as that which is now forming the upland bogs.

In the subaërial bogs the decay of the oak forest would be somewhat similar to the decay of the woods at the commencement of the submarine peats, as the growth and decay of ferns, mosses, and other denizens of a forest, would gradually stop the drainage, and produce bogs in all low-lying places; these eventually would extend their limits, until all the woods on the low lands were destroyed and covered by peat; but the stoppage of the growth of the bogs and the advent of the deal forest is more difficult to explain.

Deal trees could not be introduced or flourish on a bog until it was first drained and dried, and how this was accomplished can only be conjectured. It seems impossible that the drainage of the bogs could be due to artificial means, for although we know portions were reclaimed at different times, yet such reclamation could not have been universal, and in all parts of Ireland the pine forests seem to have existed at the same time; we are therefore forced to believe that they were introduced by natural causes. At the present day we have about five wet years, five of average character, five fine years, five of average character, and so on, in recurrent cycles; but a similar climate would not have furnished favourable conditions for the growth of the pine forests. We must therefore suppose that there was a long period of drought inauspicious to the growth of peat-producing plants, during which the bogs became drained, dried, and consolidated; subsequently the fir trees grew upon them, and came to maturity. After the growth of the forests the trees would attract the rain, and the climate would again become moist, when peat-producing plants would flourish, till eventually the pines were also destroyed and replaced by bogs. Against such a theory it must be allowed that, after the forests were destroyed, the climate ought to have again become dry, yet there does not appear to have been any material change during the last two hundred years, since the destruction of the great upland forests in Ireland recorded in the annals.

In conclusion, we may attempt to make a rough estimate of the years that have passed since the beginning of the growth of the oak forest. Some of the largest oaks in the bogs have been calculated, by their rings, to be more than two hundred years old, while fir trees, by similar indications, are found to be over one hundred years old. Many bogs are a more or less felt-like mass, but in others each year's growth is represented by a layer or lamina, and these laminæ in the brown turf are usually from fifteen to twenty in number per inch, or about two hundred in a foot, while in the black turf the average is about four hundred in a foot. From these data the age of the oaks under the previously mentioned Castleconnell bog may be as follows:—

Oak forest age . . . . about	300	years.
Five feet black turf, at 400 years a foot . .	2000	,,
Time allowed for the change of climate, say	100	,,
Deal forest age . . . . about	200	,,
Twelve feet brown turf, at 200 years a foot .	2400	,,
	5000	

Such an estimate is evidently very low, as it ignores the white turf or clearing,—also the different artificial stoppages of the growth of the peat, one considerable stoppage, at least, being during the time the road to Goig was being made and used: we, however, learn that in this part of Ireland at least five thousand years must have elapsed since the oak first began to grow.

III. THE PAST HISTORY OF OUR MOON.

By Richard A. Proctor, B.A. (Camb.),
Author of "The Sun," "The Moon," &c.

THE appearance of two treatises upon the moon, both of them considerable in dimensions, and within six months of each other, indicates the renewed interest which astronomers are taking in the study of the nearest of all the celestial bodies. It is noteworty, also, that in both these treatises,—in that by Nasmyth and Carpenter as well as in my own work,—the moon is regarded, not as a mere satellite of the earth, but as a planet, the least member of that family of five bodies circling within the asteroidal zone, to which astronomers have given the name of the terrestrial planets. There can be no question that this is the true position of the moon in the solar system. In fact, the fashion of regarding her as a mere attendant of our earth may be looked upon as the last relic of the old astronomy in which our earth figured as the fixed centre of the universe, and the body for whose sake all the celestial orbs were fashioned. In this aspect, also, the moon is a far more interesting object of research than when viewed as belonging to another and an inferior order. We are able to recognise in her appearances probably resulting from the relative smallness of her dimensions, and hence to derive probable information as to the condition of other orbs in the solar system which fall below the earth in point of size. Precisely as the study of the giant planets, Jupiter and Saturn, has led astronomers to infer that certain peculiarities must result from vastness of dimensions, so the study of the dwarf planets, Mars, our moon, and Mercury, may indicate the relations we are to associate with inferiority of size.

This thought immediately introduces us to another conception which causes us to regard with even greater interest the evidence afforded by the moon's present condition. It can scarcely be questioned that the size of any member of the solar system, or rather the quantity of matter in its orb, assigns, so to speak, the duration of that orb's existence, or rather of the various stages of that existence. The smaller body must cool more rapidly than the larger, and hence the various periods during which the former is fit for this or that purpose of planetary life (I speak with purposed vagueness here) are shorter than the corresponding periods in the life of the latter. Thus the sun, viewed in this way, is the youngest member of the solar system, while the tiniest members of the asteroid family, if not the oldest in reality, are the oldest to which the telescope has introduced us. Jupiter and Saturn come next to the sun in youth ; they are still passing through the earliest stages of planetary existence, even if we ought not rather to adopt that theory of their condition which regards them as subordinate suns, helping the central sun to support life on the satellites which circle around them. Uranus and Neptune are in a later stage, and perchance when telescopes have been constructed large enough to study these planets with advantage, we may learn something of that stage, interesting as being intermediate to the stages through which our earth and Venus on the one hand, and the giant brothers Jupiter and Saturn on the other, are at present passing. After our earth and Venus, which are probably at about the same stage of planetary development (though owing to the difference in their position they may not be equally adapted for the support of life) we come to Mars and Mercury, both of which must be regarded as in all probality much more advanced and in a sense more aged than the earth on which we live. In a similar sense,—even as an ephemeron is more aged after a few hours of existence than a man after as many years,—the small planet which we call " our moon " may be described as in the very decrepitude of planetary existence, nay (some prefer to think), as even absolutely dead, though its lifeless body still continues to advance upon its accustomed orbit, and to obey the law of universal attraction.

Considerations such as these give singular interest to the discussion of the past history of our moon, though they add to the difficulty of interpreting the problems she presents to us. For we have manifestly to differentiate between the effects due to the moon's relative smallness on the one hand, and those due to her great age on the other. If we could believe the moon to be an orb which simply represents the condition to which our earth will one day attain, we could study her peculiarities of appearance with some hope of understanding how they had been brought about, as well as of learning from such study the future history of our own earth. But clearly the moon has had another history than our earth. Her relative smallness has led to relations such as the earth never has presented and never will present. If our earth is, as astronomers and physicists believe, to grow dead and cold, all life perishing from her surface, it is tolerably clear from what we already know of her history that the appearance she will present in her decrepitude will be utterly unlike that presented by the moon. Grant that after the lapse of enormous time-intervals the oceans now existing on the earth will be withdrawn beneath her solid crust, and even (which seems incredible) that at a more distant future the atmosphere now surrounding her will have become greatly reduced in quantity either by similar withdrawal or in any other manner, yet the surface of the earth would present few features of resemblance to that of the moon. Viewed from the distance at which we view the moon there would be few crateriform mountains indeed compared with those on the moon; those visible would be small by comparison with lunar craters even of medium dimensions; and the radiated regions seen on the moon's surface would have no discernible counterpart on the surface of the earth. The only features of resemblance, under the imagined conditions, would be probably the partially flat sea bottoms (though these would bear a different proportion to the more elevated regions) and the mountain ranges, the only terrestrial features of volcanic disturbance which would be relatively more important than their lunar counterparts.

I do not purpose, however, to discuss the probable future of the earth, having only indicated the differences just touched upon, in order to remind the reader at the outset that we have not in "the moon" a representation of the earth at any stage of her history. Other and different relations are presented for our consideration, although it may well be that by carefully discussing them we may learn somewhat respecting our earth, as also respecting the past history and future development of the solar system.

I have already, on two occasions, discussed in these pages some of the problems presented by the observed condition of the moon's surface, and in my treatise on the moon, I have in several places indicated the views towards which my study of the subject tended. But I have not attempted to present any general theory on the subject, feeling, indeed, that it was one which presented too many difficulties to be hastily dealt with. It seems to me, however, that the enunciation by Messrs. Nasmyth and Carpenter, of somewhat definite theories respecting the moon's surface, affords me a favourable opportunity for advancing considerations which I have had much in my thoughts during the last five or six months, and which appear to me to accord more satisfactorily with observed lunar appearances on the one hand as well as with known terrestrial and probable cosmical relations on the other, than the theories advanced in the treatise above referred to.

It appears reasonable to regard the moon, after her first formation as a distinct orb, as presenting the same general characteristics that we ascribe to our earth in its primary stage as a planet. In one respect the moon, even at that early stage, may have differed from the earth. I refer to its rotation, the correspondence between which and its revolution may probably have existed from the moon's first formation. But this would not materially have affected the relations with which we have to deal at present. We may apply, then, to the moon the arguments which have been applied to the discussion of the first stages of our earth's history.

Adopting this view, we see that at the first stage of its existence as an independent planet, the moon must have been an intensely heated gaseous globe, glowing with inherent light, and undergoing a process of condensation, "going on at first at the surface only, until by cooling it must have reached the point where the gaseous centre was exchanged for one of combined and liquefied matter." To apply now to the moon at this stage the description which Dr. Sterry Hunt gives of the earth:—"Here commences the chemistry of the moon. So long as the gaseous condition of the moon lasted, we may suppose the whole mass to have been homogeneous; but when the temperature became so reduced that the existence of chemical compounds at the centre became possible, those which were most stable at the elevated temperature then prevailing, would be first formed. Thus, for example, while compounds of oxygen with mercury, or even with hydrogen, could not exist, oxides of silicon, aluminium, calcium, magnesium, and iron, might be formed and condensed in a liquid form at the centre of the globe. By progressive cooling still other elements would be removed from the gaseous mass, which would form the atmosphere of the non-gaseous nucleus." "The processes of condensation and cooling having gone on until those elements which are not volatile in the heat of our ordinary furnaces were condensed into a liquid form, we may here inquire what would be the result on the mass of a further reduction of temperature. It is generally assumed that in the cooling of a liquid globe of mineral matter congelation would commence at the surface, as in the case of water; but water offers an exception to most other liquids, inasmuch as it is denser in the liquid than in the solid form. Hence, ice floats on water, and freezing water becomes covered with a layer of ice which protects the liquid below. Some metals and alloys resemble water in this respect. With regard to most other earthy substances, and notably the various minerals and earthy compounds like those which may be supposed to have made up the mass of the molten globe, the case is entirely different. The numerous and detailed experiments of Charles Deville and those of Delesse, besides the earlier ones of Bischof, unite in showing that the density of fused rocks is much less than that of the crystalline products resulting from their slow cooling, these being, according to Deville, from one-seventh to one-sixteenth heavier than the fused mass, so that if formed at the surface they would, in obedience to the laws of gravity, tend to sink as soon as formed."

Here it has to be noted that possibly there existed a period (for our earth as well as for the moon) during which, notwithstanding the relations indicated by Dr. Hunt, the exterior portions of the moon were solid, while the interior remained liquid. A state of things corresponding to what we recognise as possible in the sun may have existed. For although undoubtedly any liquid matter forming in the sun sinks in obedience to the laws of gravity towards the centre, yet the greater heat which it encounters as it sinks must vapourise it, notwithstanding increasing pressure, so that it can only remain liquid near the region where rapid radiation allows of sufficient cooling to produce liquefaction. And in the same way we may conceive that the solidification taking place at any portion of the surface of the moon's or the earth's liquid globe, owing to rapid radiation of heat thence, although it might be followed immediately by the sinking of the solidified matter, would yet result in the continuance (rather than the existence) of a partially solid crust. For the sinking solid matter, though subjected to an increase of pressure (which, in the case of matter expanding on liquefaction, would favour solidification) would nevertheless, owing to the great increase of heat, become liquefied, and expanding would no longer be so much denser* than the liquid through which it was sinking as to continue to sink rapidly.

Nevertheless, it is clear that after a time the heat of the interior parts of the liquid mass would no longer suffice to liquefy the solid matter descending from the surface, and then would commence the process of aggregation at the centre described by Dr. Hunt. The matter forming the solid centre of the earth consists probably of metallic and metalloidal compounds of elements denser than those forming the known portions of the earth's crust.* In the case of the moon, whose mean density is very little greater than the mean density of the matter forming the earth's crust, we must assume that the matter forming the solid nucleus at that early stage was relatively less in amount, or else that we may attribute part of the difference to the comparatively small force with which lunar gravity operated during various stages of contraction and solidification.

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* It would still be somewhat denser, because under the circumstances it would be somewhat cooler.

In the case of the moon, as in that of the earth, before the last portions became solidified, there would exist a condition of imperfect liquidity, as conceived by Hopkins, "preventing the sinking of the cooled and heavier particles, and giving rise to a superficial crust, from which solidification would proceed downwards. There would thus be enclosed between the inner and outer solid parts a portion of uncongealed matter," which may be supposed to have retained its liquid condition to a late period, and to have been the principal seat of volcanic action, whether existing in isolated reservoirs or subterranean lakes, or whether, as suggested by Scrope, forming a continuous sheet surrounding the solid nucleus.

Thus far we have had to deal with relations more or less involved in doubt. We have few means of forming a satisfactory opinion as to the order of the various changes to which, in the first stages of her existence as a planet, our moon was subject. Nor can we clearly define the nature of those changes. In these matters, as with the corresponding processes in our earth's case, there is much room for variety of opinion.

But few can doubt that, by whatever processes such condition may have been attained, the moon, when her surface began to form itself into its present appearance, consisted of a globe partially molten surrounded by a crust at least partially solidified. Some portions of the actual surface may have remained liquid or viscous later than others; but at length the time must have arrived when the radiating surface was almost wholly solid. It is from this stage that we have to trace the changes which have led to the present condition of the moon's surface.

It can scarcely be questioned that those seismologists are in the right who have maintained in recent times the theory that in the case of a cooling globe, such as the earth or moon at the stage just described, the crust would in the first place contract more quickly than the nucleus, while later the nucleus would contract more quickly than the crust. This amounts, in fact, to little more than the assertion that the process of heat radiation from the surface would be more rapid, and so last a shorter time than the process of conduction by which in the main the nucleus would part with its heat. The crust would part rapidly with its heat, contracting upon the nucleus; but the very rapidity (relative) of the process, by completing at an early stage the radiation of the greater portion of the heat originally belonging to the crust, would cause the subsequent radiation to be comparatively slow, while the conduction of heat from the nucleus to the crust would take place more rapidly, not only relatively but actually.

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* It is thus, and not by the effects due to increasing pressure (effects which do not increase beyond a certain point) that we are to explain the fact that the earth's density as a whole is about twice the mean density of the matters which form its solid surface. It may be that this consideration, supported by the results of recent experimental researches, may give a significance hitherto not noted to the relatively small mean density of the moon.

Now it is clear that the results accruing during the two stages into which we thus divide the cooling of the lunar globe would be markedly different. During the first stage forces of tension (tangential) would be called to play in the lunar crust; during the later stage the forces would be those of pressure.

Taking the earlier stage, during which the forces would be tensional, let us consider in what way these forces would operate.

At the beginning, when the crust would be comparatively thin, I conceive that the more general result of the rapid contraction of the crust would be the division of the crust into segments, by the formation of numerous fissures due to the lateral contraction of the thin crust. The molten matter in these fissures would film over rapidly, however, and all the time the crust would be growing thicker and thicker, until at length the formation of distinct segments would no longer be possible. The thickening crust, plastic in its lower strata, would now resist more effectively the tangential tensions, and when yielding would yield in a different manner. At this stage, in all probability, it was that processes such as those illustrated by Nasmyth's globe experiments took place, and that from time to time the crust yielded at particular points, which became the centres of systems of radiating fissures. Before proceeding, however, to consider the results of such processes, let it be noted that we have seen reason to believe that among the very earliest lunar formations would be rifts breaking the *ancient* surface of the lunar crust. I distinguish in this way the ancient surface from portions of surface whereof I shall presently have to speak as formed at a later time.

Now let us conceive the somewhat thickened crust contracting upon the partially fluid nucleus. If the crust were tolerably uniform in strength and thickness we should expect to find it yielding (when forced to yield) at many points, distributed somewhat uniformly over its extent. But this would not be the case if—as we might for many reasons expect—the crust were wanting in uniformity. There would be regions where the crust would be more plastic, and so readier to yield to the tangential tensions. Towards such portions of the crust the liquid matter within would tend, because there alone would room exist for it. The down-drawing, or rather in-drawing, crust elsewhere would force away the liquid matter beneath, towards such regions of less resistance, which would thus remain at (and be partly forced to) a higher level. At length, however, the increasing tensions thus resulting would have their natural effect; the crust would break open at the middle of the raised region, and in radiating rifts, and the molten matter would find vent through the rifts as well as at the central opening. The matter so extruded, being liquid, would spread, so that—though the radiating nature of the rifts would still be indicated by the position of the extruded matter—there would be no abrupt changes of level. It is clear, also, that so soon as the outlet had been formed the long and slowly sloping sides of the region of elevation would gradually sink, pressing the liquid matter below towards the centre of outlet, whence it would continue to pour out so long as this process of contraction continued. All round the borders of the aperture the crust would be melted, and would continue plastic long after the matter which had filled the fissures and flowed out through them had solidified. Thus there would be formed a wide circular orifice, which would from the beginning be considerably above the mean level of the moon's surface, because of the manner in which the liquid matter within had been gathered there by the pressure of the surrounding slopes.*

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* I have occasion to make some remarks at this stage to avoid possible and (my experience has shown me) not altogether improbable misconception, or even misrepresentation. The theory enunciated above will be regarded by some, who may have read a certain review of my Treatise on the Moon, as totally different from what I have advocated in that work, and, furthermore, as a theory which I have borrowed from the aforesaid review. I should not be particularly concerned if I had occasion to modify views I had formerly expressed, since I apprehend that every active student of science should hope, rather than dread, that as his work proceeds he would form new opinions. And again, I am not in the least anxious to claim priority as to the enunciation of any theory, conceiving that claims of the kind seem as a rule indicative of a singular poverty of intellect on the part of those who make them (as though, having given birth to one good thought, they had no hope of ever being

Moreover, around the orifice, the matter outflowing as the crust continued to contract would form a raised wall. Until the time came when the liquid nucleus began to contract more rapidly than the crust, the large crateriform orifice

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delivered of another). Accordingly I have never, on the one hand, found occasion—to the best of my recollection—to claim a disputed priority; nor, on the other, have I ever been unwilling to abandon a theory which I have formerly maintained on insufficient grounds. (I need only point to my article on "Mars," in the "Quarterly Journal of Science," for April, 1873, as an illustrative instance, since I there not only abandon a theory I had once regarded with favour, but advocate carefully the theory advanced against it.) But the present instance is a somewhat peculiar one. In the "Saturday Review" for March 28th there is a paper which discusses lunar phenomena with considerable acumen. Of course there is the giant-making process which in the "Saturday Review" always precedes the process of giant-killing. The work of Messrs. Nasmyth and Carpenter is very warmly praised as a preliminary to the annihilation of their fundamental hypothesis. "We honour," says the condescending reviewer, "the courage which is daunted by no difficulty, and we feel that the authors were bound to make their theory a complete one; but we should have not the less felt bound to point out the glaring absurdities of this hypothesis had not the more than diffident tone in which the authors themselves speak of it rendered such a proceeding unnecessary." I am treated somewhat differently. A theory which I touched on first in these pages—the theory, namely, that some of the lunar markings on the moon's surface may have been due to meteoric downfalls in the long past ages when that surface was plastic, and meteor flights were more important than now—is described as one which "Mr. Proctor would have us believe," although I said in so many words "that I should certainly not care to maintain that as the true theory;" and is then summarily dismissed as a *facetia*. But while I am thus credited with insistance on a theory which I merely sketched as one not to be altogether overlooked in discussing peculiarities as yet not satisfactorily interpreted, the reviewer wholly omits to mention that much earlier in my book I had advocated, in a much more definite manner, a view closely resembling (so far as it relates to the large craters) that which he himself advances as preferable to Nasmyth's. I quote in full the passage in which I indicate and advocate, briefly but clearly, the theory urged above. At page 255 of my work on the "Moon," after describing the radiations from Tycho and other craters, I proceed—"It appears to me impossible to refer these phenomena to any general cause but the reaction of the moon's interior overcoming the tension of the crust, and to this degree Nasmyth's theory seems correct; but it appears manifest, also, that the crust cannot have been fractured in the ordinary sense of the word. Since, however, it results from Mallet's investigations that the tension of the crust is called into play in the earlier stages of contraction, and its power to resist contraction in the later stages,—in other words, since the crust at first contracts faster than the nucleus, and afterwards not so fast as the nucleus,—we may assume that the radiating systems were formed in so early an era that the crust was plastic. And it seems reasonable to conclude that the outflowing matter would retain its liquid condition long enough (the crust itself being intensely hot) to spread widely,—a circumstance which would account at once for the breadth of many of the rays, and for the restoration of level to such a degree that no shadows are thrown. It appears probable, also, that not only (which is manifest) were the craters formed later which are seen around and upon the radiations, but that the central crater itself acquired its actual form long after the epoch when the rays were formed." It will be manifest that the method here indicated as that by which the central crater acquired its actual form long after the rays had been formed, could only be that which the reviewer has indicated in the following passage:—"Assuming that the moon was once covered by a crust of rock, under a portion of which would be full to the brim (or nearly so), at all times, with occasional overflows; and as a writer who has recently adopted this theory has remarked—"We should ultimately have a large central lake of lava surrounded by a range of hills, terraced on the outside,—the lake filling up the space they enclosed."

The crust might burst in the manner here considered, at several places at the same—or nearly the same—time, the range of the radiating fissures depending on the extent of the underlying lakes of molten matter thus finding their outlet; or there might be a series of outbursts at widely separated intervals of time, and at different regions, gradually diminishing in extent as the crust gradually thickened and the molten matter beneath gradually became reduced in relative amount. Probably the latter view should be accepted, since if we consider the three systems of radiations from Copernicus, Aristarchus, and Kepler, which were manifestly not formed contemporaneously, but in the order in which their central craters have just been named, we see that their dimensions diminished as their date of formation was later. According to this view we should regard the radiating system from Tycho as the oldest of all these formations.

At this very early stage of the moon's history, then, we regard the moon as a somewhat deformed spheroid, the regions whence the radiations extended being the highest parts, and the regions farthest removed from the ray centres being the lowest.* To these lower regions whatever was liquid on the moon's surface would find its way. The down-flowing lava would not be included in this description, as being rather viscous than liquid; but if any water

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at least lay melted rock of the same nature, nothing is more natural than that the contraction of the crust should cause great overflows of lava, which would spread far and wide; the outside portions would cool, but those near the centre of disturbance would be kept at their original temperature, and the tendency would be (as is so often noticed in eruptions) to melt the already solidified rock with which it was in contact, and thus the orifice would become wider."

* Where several ray centres are near together, a region directly between two ray centres would be at a level intermediate between that of the ray centres and that of a region centrally placed within a triangle or quadrangle of ray centres; but the latter region might be at a higher level than another very far removed from the part where the ray centres were near together. For instance, the space in the middle of the triangle having Copernicus, Aristarchus, and Kepler at its angles (or more exactly between Milichius and Bessarion) is lower than the surface around Hortensius (between Copernicus and Kepler), but not so low as the Mare Imbrium, far away from the region of ray centres of which Copernicus, Aristarchus, and Kepler are the principal.

existed at that time it would occupy the depressed regions which at the present time are called Maria or Seas. It is a question of some interest, and one on which different opinions have been entertained, whether the moon at any stage of its existence had oceans and an atmosphere corresponding or even approaching in relative extent to those of the earth. It appears to me that, apart from all the other considerations which have been suggested in support of the view that the moon formerly had oceans and an atmosphere, it is exceedingly difficult to imagine how, under any circumstances, a globe so large as the moon could have been formed under conditions not altogether unlike, as we suppose, those under which the earth was formed (having a similar origin, and presumably constructed of the same elements), without having oceans and an atmosphere of considerable extent; the atmosphere would not consist of oxygen and nitrogen only or chiefly, any more than, in all probability, the primæval atmosphere of our own earth was so constituted. We may adopt some such view of the moon's atmosphere—*mutatis mutandis*—as Dr. Sterry Hunt has adopted respecting the ancient atmosphere of the earth. Hunt, it will be remembered, bases his opinion on the former condition of the earth by conceiving an intense heat applied to the earth as now existing, and inferring the chemical results. "To the chemist," he remarks, "it is evident that from such a process applied to our globe would result the oxidation of all carbonaceous matter; the conversion of all carbonates, chlorides, and sulphates into silicates; and the separation of the carbon, chlorine, and sulphur in the form of acid gases; which, with nitrogen, watery vapour, and an excess of oxygen, would form an exceedingly dense atmosphere. The resulting fused mass would contain all the bases as silicates, and would probably nearly resemble in composition certain furnace-slags or basic volcanic glasses. Such we may conceive to have been the nature of the primitive igneous rock, and such the composition of the primeval atmosphere, *which must have been one of very great density*." All this, with the single exception of the italicised remark, may be applied to the case of the moon. The lunar atmosphere would not probably be dense at that primeval time, even though constituted like the terrestrial atmosphere just described. It would perhaps have been as dense, or nearly so, as our present atmosphere. Accordingly condensation would take place at a temperature not far from the present boiling-point, and the lower levels of the half-cooled crust would be drenched with a heated solution of hydrochloric acid, whose decomposing action would be rapid, though not aided—as in the case of our primeval earth—by an excessively high temperature. "The formation of the chlorides of the various bases and the separation of silica would go on until the affinities of the acid were satisfied." "At a later period the gradual combination of oxygen with sulphurous acid would eliminate this from the atmosphere in the form of sulphuric acid." "Carbonic acid would still be a large constituent of the atmosphere, but thenceforward (that is, after the separation of the compounds of sulphur and chlorine from the air) there would follow the conversion of the complex aluminous silicates, under the influence of carbonic acid and moisture, into a hydrated silicate of alumina or clay, while the separated lime, magnesia, and alkalies would be changed into bicarbonates, and conveyed to the sea in a state of solution."

It seems to me that it is necessary to adopt some such theory as to the former existence of lunar oceans, in order to explain some of the appearances presented by the so-called lunar seas. As regards the present absence of water we may adopt the theory of Frankland, that the lunar oceans have withdrawn beneath the crust as room was provided for them by the contraction of the nucleus. I think, indeed, that there are good grounds for looking with favour on the theory of Stanislas Meunier, according to which the oceans surrounding any planet—our own earth or Mars, for example—are gradually withdrawn from the surface to the interior. And in view of the enormous length of the time intervals required for such a process, we must consider that while the process was going on the lunar atmosphere would not only part completely with the compounds of sulphur, chlorine, and carbon, but would be even still further reduced by chemical processes acting with exceeding slowness, yet effectively in periods so enormous. But without insisting on this consideration, it is manifest that—with very reasonable assumptions as to the density of the lunar atmosphere in its original complex condition—what would remain after the removal of the chief portion by chemical processes, and after the withdrawal of another considerable portion along with the seas beneath the lunar crust, would be so inconsiderable in quantity as to accord satisfactorily with the evidence which demonstrates the exceeding tenuity of any lunar atmosphere at present existing.

These considerations introduce us to the second part of the moon's history,—that corresponding to the period when the nucleus was contracting more rapidly than the crust.

One of the first and most obvious effects of this more rapid nuclear contraction would be the lowering of the level of the molten matter, which up to this period had been kept up to, or nearly up to, the lips of the great ringed craters. If the subsidence could place intermittently there would result a terracing of the interior of the ringed elevation, such as we see in many lunar craters. Nor would there be any uniformity of level in the several crater floors thus formed, since the fluid lava would not form parts of a single fluid mass (in which case, of course, the level of the fluid surface would be everywhere the same), but would belong to independent fluid masses. Indeed it may be noticed that the very nature of the case requires us to adopt this view, since no other will account for the variety of level observed in the different lunar crater-floors. If these ceased to be liquid at different times, the independence of the fluid masses is by that very fact established; and if they ceased to be liquid at the same time, they must have been independent, since, if communication had existed between them, they would have shown the uniformity of surface which the laws of hydrostatics require.*

The next effect which would follow from the gradual retreat of the nucleus from the crust (setting aside the withdrawal of lunar seas) would be the formation of corrugations, —in other words, of mountain-ranges. Mallet describes the formation of mountain-chains as belonging to the period when "the continually increasing thickness of the crust remained such that it was still as a whole flexible enough, or opposed sufficient resistance of crushing to admit of the uprise of mountain-chains by resolved tangential pressures." Applying this to the case of the moon, I think it is clear that—with her much smaller orb and comparatively rapid rate of cooling—the era of the formation of mountain-chains would be a short one, and that these would therefore form a less important characteristic of her surface than of the earth's. On the other hand, the period of volcanic activity which would follow that of chain-formation would be *relatively* long continued; for regarding this period as beginning when the thickness of the moon's crust had become too great to admit of adjustment by corrugation, the comparatively small pressure to which the whole mass of the moon had been subjected by lunar gravity, while it would on the one hand cause the period to have an earlier commencement

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* It is important to notice that we may derive from these considerations an argument as to the condition of the fluid matter now existing beneath the solid crust of the earth.

(relatively), and on the other would leave greater play to the effects of contraction. Thus we can understand why the signs of volcanic action, as distinguished from the action to which mountain-ranges are due, should be far more numerous and important on the moon than on the earth.

I do not, however, in this place enter specially into the consideration of the moon's stage of volcanic activity, because already, in the pages of my Treatise on the Moon (Chapter VI.) I have given a full account of that portion of my present subject. I may make a few remarks, however, on the theory respecting lunar craters touched on in my work on "The Moon." I have mentioned the possibility that some among the enormous number of ring-shaped depressions which are seen on the moon's surface may have been the result of meteoric downfalls in long past ages of the moon's history. One or two critics have spoken of this view as though it were too fantastic for serious consideration. Now, though I threw out the opinion merely as a suggestion, distinctly stating that I should not care to maintain it as a theory, and although my own opinion is unfavourable to the supposition that any of the more considerable lunar markings can be explained in the suggested way, yet it is necessary to notice that on the general question whether the moon's surface has been marked or not by meteoric downfalls scarcely any reasonable doubts can be entertained. For, first, we can scarcely question that the moon's surface was for long ages plastic, and though we may not assign to this period nearly so great a length (350 millions of years) as Tyndall—following Bischoff—assigns to the period when our earth's surface was cooling from a temperature of 2000° C. to 200°, yet still it must have lasted millions of years; and, secondly, we cannot doubt that the process of meteoric downfall now going on is not a new thing, but, on the contrary, is rather the final stage of a process which once took place far more actively. Now Prof. Newton has estimated, by a fair estimate of observed facts, that each day on the average 400 millions of meteors fall, of all sizes down to the minutest discernible in a telescope, upon the earth's atmosphere, so that on the moon's unprotected globe—with its surface one-thirteenth of the earth's—about 30 millions fall each day, even at the present time. Of large meteoric masses only a few hundreds fall each year on the earth, and perhaps about a hundred on the moon; but still, even at the present rate of downfall, millions of large masses must have fallen on the moon during the time when her surface was plastic, while presumably a much larger number—including many much larger masses—must have fallen during that period. Thus, not only without straining probabilities, but by taking only the most probable assumptions as to the past, we have arrived at a result which compels us to believe that the moon's surface has been very much marked by meteoric downfall, while it renders it by no means unlikely that a large proportion of the markings so left would be discernible under telescopic scrutiny; so that strong evidence exists in favour of that hypothesis which one or two writers (who presumably have not given great attention to the recent progress of meteoric astronomy) would dismiss "without consideration" (the way, doubtless, in which they have dismissed it).

I would, in conclusion, invite those who have the requisite leisure to a careful study of the distribution of various orders of lunar marking. It would be well if the moon's surface were isographically charted, and the distribution of the seas, mountain-ranges, and craters of different dimensions and character, of rills, radiating streaks, bright and dark regions, and so on, carefully compared *inter se*, with the object of determining whether the different parts of the moon's surface were probably brought to their present condition during earlier or later periods, and of interpreting also the significance of the moon's characteristic peculiarities. In this department of Astronomy, as in some others, the effectiveness of well-devised processes of charting has been hitherto overlooked.

IV. MODERN RESEARCHES IN TROPICAL ZOOLOGY.*

ORDINARY modern books of travel are justly ranked among the dreariest of literary productions. Their authors treat the countries which they visit merely as a stage for the display of their own imagined perfections, their omniscience, their courage, their skill as sportsmen, and above all, the importance of their mission to the distinguished personages with whom they became acquainted. To all this the work before us offers a complete and a delightful contrast. Mr. Belt does not obtrude his own personality upon us. Like all genuine men, he forgets "self" over his subject. Instead of informing us whether or no he received "the salary of an ambassador and the treatment of a gentleman," he scatters before us, broadcast, facts, interesting and novel; valuable hints for future research, and generalisations which will amply repay a close examination. Not alone the zoologist, the botanist, the geologist, but the antiquarian, the ethnologist, the social philosopher, and the meteorologist, will each find in these pages welcome additions to his store of knowledge and sound materials for study. With all this, the work is not a mere dry catalogue of facts, such as Henry Cavendish might have written: it is eminently a "readable book." Though without any effort at fine writing, the beautiful forest landscapes of Central America are brought vividly before us. For instances, we refer our readers to the work itself.

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* The Naturalist in Nicaragua; a Narrative of a Residence at the Gold Mines of Chontales. By THOMAS BELT, F.G.S. London: John Murray.

In his professional investigations of the gold deposits of Chontales, the author was struck with the scarcity of alluvial gold in the valleys, even in the neighbourhood of rich veins of auriferous quartz. This fact, reminding the observer of the similar scarcity in the valleys of Nova Scotia and North Wales, can be explained "on the supposition that the ice of the glacial period was not confined to extra-tropical lands, but, in Central America, covered all the higher ranges and descended to at least as low as the line of country now standing at two thousand feet above the sea, and probably much lower." That glaciers would have this effect is indubitable. As the author remarks: "When the denuding agent was water, the rocks were worn away, and the heavier gold left behind at the bottom of the alluvial deposits; but when the denuding agent was glacier-ice, the stony masses and their metallic contents were carried away, or mingled together in the unassorted moraines."

We may, at first sight, feel sceptical concerning the existence of glaciers in the low grounds within 13° of the equator. But the testimony of the rocks appears irresistible. "The evidences of glacial action were as clear as in any Welsh or Highland valley. There were the same rounded and smoothed masses of rock, the same moraine-like accumulations of unstratified sand and gravel, the same transported boulders that could be traced to their parent rocks, several miles distant." Glacial scratches were not, indeed, observed; but these are rarely detected on surfaces of rock exposed to the atmosphere. We must, also, remember that Professor Hart has found glacial drift extending from Patagonia all through Brazil to Pernambuco, whilst the late lamented Agassiz has observed glacial moraines up to the equator. On a former journey Mr. Belt discovered in the province of Maranham, in Brazil, a great drift deposit apparently of glacial origin. Hence, he, very justifiably, thinks it highly probable that the ice deposits of the glacial period were far more extensive than has been generally supposed, existing at once in both the northern and southern hemispheres, and leaving, in America at least, only the lower lands of the tropics free from the icy covering.

Were the causes of such a reduction of the earth's general temperature cosmic or merely terrestrial? The author does not enter minutely into this question, though, with Professor Heer, he considers that the cold of the glacial period, like the warmth of the miocene epoch, "cannot be explained by any re-arrangement of the relative positions of land and water." It is very true that were the circum-polar lands, British North America and the Russian empire, deeply submerged beneath the ocean, and were a corresponding amount of land raised where now rolls the inter-tropical Pacific, the temperature of the world would be much ameliorated. But the very evidence of the heat of the miocene ages,—the existence, at that time of the beech, the hazel, and the plane in Spitzbergen, in north latitude 78°, proves that the polar regions were not an unbroken expanse of water. Similarly, the proofs of glacial action within the torrid zone show that during the glacial period land was by no means wanting between the tropics. It seems, therefore, highly probable, that in regarding these alternating epochs of heat and cold, "we are face to face with a problem whose solution must be attempted, and doubtless completed, by the astronomer."

But there is another phase of the subject to which the attention of the author is mainly given. Every botanist and geologist, on hearing of these enormous ice-deposits in what are now some of the most luxuriant climates of the world, will ask what must have become of all tropical forms of organic life? The very *tierras calientes* in those days, instead of towering palms and of epiphytal arads and orchids, must have possessed a vegetation little richer than that of England or Germany in the present order of things. Heliconii and Morphos can never have unfolded their delicate wings on the chill blast from the ice-deserts. The author meets this difficulty by the hypothesis that "a refuge was found for many species on lands now below the level of the ocean, but then uncovered by the lowering of the sea, consequent upon the immense quantity of water locked up in the form of ice, and piled upon the continents." A variety of evidence is adduced in support of this view. The distribution of animal life over small islands now separated by shallow seas is readily explained on such supposition. Professor Hartt found reason to believe that during the time of the drift, Brazil stood at a much higher level than at present. Mr. Alfred Tylor considers that during the glacial epoch the level of the sea must have been reduced at least 600 feet, an estimate which our author extends to 1000. Mr. Wallace, in his work on the Malay Archipelago, infers from the distribution of animal life that Borneo, Java, and the more western islands of the group were at one time connected with each other, and with the main land of Asia, while New Guinea and the islands to the eastward were joined to Australia. The Cyclopean ruins found in certain islets of the Pacific, and utterly out of keeping with their present size and population, point in the same direction. Easter Island, as the author observes, could never have supported the race that reared such monuments. But if the present island was once one of a chain of hills overlooking wide and populous lowlands—now submerged beneath the blue waters of the Pacific—such remains become intelligible.

Mr. Belt's theory, as we may provisionally call it, furnishes the key to a number of ancient traditions on both sides of the Atlantic.

May not the Atlantis of Plato, of Theopompus, and of Proclus, finally swallowed up by the sea, have been "that great continent in the Atlantic, on which the present West Indian Islands were mountains?" The warlike and predatory character ascribed to its inhabitants by Greek and Egyptian story is in full harmony with their probably Carib origin. Mr. Belt's theory throws also a wonderful light upon the sagas of a universal deluge current, according to Catlin, among one hundred and twenty different tribes of North and South America. Those low-lying lands, if they existed at all, must have been the refuge during the glacial epoch, not merely of the principal forms of vegetable and animal life, but of the human race. Whatever civilisation existed must have had there its seat. Suppose, now, that the temperature of the earth experienced, from some unknown cosmical cause, a sudden elevation. The glaciers, or rather the ice-caps, resting on the present continents, are suddenly converted into torrents of water rushing down to the sea. The ocean level rapidly rises. Atlantis and all the other populous regions of the earth are engulphed. A hundred fathoms deep roll the waters over fields and cities, whilst a few only of the inhabitants escape in boats or find shelter on some lofty mountain.

Much, however, requires to be done, before such a theory can claim recognition among the established doctrines of science. Mr. Belt himself insists on the necessity of a careful and thorough going verification of his hypothesis. "When geologists have mapped out the limits of ancient glacier and continental ice all over the world, it will be possible to calculate the minimum amount of water that was abstracted from the sea; and if by that time hydrographers have shown on their charts the shoals and submerged banks that would be laid dry, fabled Atlantis will rise before our eyes between Europe and America, and in the Pacific the Malay Archipelago will give place to the Malay continent." In our opinion, a knowledge of the distribution of animal life, much more accurate and general than we now possess, will also be found needful for the full solution of the problem. Is it not also possible that by a careful examination of the less deeply submerged banks and shoals, evidence as to the presence or absence of traces of former human activity might be obtained?

We must not, however, forget that Mr. Belt's interesting hypothesis is not without a rival. The doctrine of areas of subsidence and elevation so ably expounded by Mr. Darwin in his Naturalists' Voyage, accounts for many of the same phenomena by an alteration of the level, not of the sea, but of the continents, and certainly agrees with many recognised facts. We have not space to examine in how far the two theories are necessarily antagonistic and mutually exclusive. It is plain that some of the Pacific Islands—which according to both views are the mountains of a now submerged continent—are still gradually subsiding. It is no less manifest that other portions of the earth's surface, *e.g.*, certain parts of the South American coast, are gradually rising. The evidence of both these progressive variations of level may be found in the above-mentioned work of Mr. Darwin. The phenomena of the atolls, likewise, appear to us to agree better with the assumption of a gradual subsidence of the dry land than with its inundation by the sudden influx of water. On the other hand, the Beltian hypothesis, harmonises best with the deluge-traditions of the old and the new world.

On Mr. Belt's view, we should naturally expect to find the fauna and the flora of any large island closely correspond to that of the adjacent continent, with which during the glacial period it would have been connected. Yet to this rule—if rule it be—there are notable exceptions of which account must be taken. Why should the larger Antilles be free from carnivora? Cuba and Haiti would have afforded, in their glens and woods, ample and congenial lurking-grounds for the jaguar and the puma. Nor, to our knowledge, have these islands ever been so populous and so civilised that such unwelcome inmates would have been extirpated. Ceylon is separated from the mainland of India by a shallow sea. If the general level of the waters were reduced by 1000, or even by 600 feet, the space between the island and the continent would be bridged over. Yet, on the authority of Sir E. Tennant, there are more points of disagreement than of resemblance between the respective animal and vegetable forms on both sides of the straits. We are not aware of the depth of the Channel of the Mozambique. But scarcely could two richly developed faunas differ more strikingly than those of Madagascar and of South-eastern Africa. The monkeys of the continent are, in the island, replaced by lemurs. The cats and the gazelles in which Africa abounds are, we believe, totally wanting in Madagascar. The insect-world in particular shows a striking divergence. Madagascar is remarkably rich in those "animated jewels," the Cetoniadæ; but the species, and for the most part the genera, are distinct from those of Southern Africa, and, where not peculiar, remind us rather of forms developed in the Malay Archipelago.

But Mr. Belt's work is so replete with interest that we must, unwillingly indeed, desist from any further scrutiny of his geological speculations. His instances of the intelligence of ants are highly instructive:—"One day when watching a small column of these ants (*Eciton hamata*) I placed a little stone on one of them to secure it. The next that approached, as soon as it discovered its situation, ran backwards in an agitated manner and soon communicated the intelligence to the others. They rushed to the rescue; some bit at the stone and tried to move it, others seized the prisoner by the legs and tugged with such force that I thought the legs would be pulled off, but they persevered till they got the captive free. I next covered one up with a piece of clay, leaving only the ends of its antennæ projecting. It was soon discovered by its fellows, which set to work immediately, and by biting off pieces of the clay, soon liberated it. Another time I found a very few of them passing along at intervals. I confined one of these under a piece of clay, at a little distance from the line, with its head projecting. At last an ant discovered it and tried to pull it out, but could not. It immediately set off at a great rate, and I thought it had deserted its comrade, but it had only gone for assistance, for in a short time about a dozen ants came hurrying up, evidently fully informed of the circumstances of the case, for they made directly for their imprisoned comrade and soon set him free. I do not see how this action could be instinctive. It was sympathetic help, such as man only among the higher mammalia shows."

We need not feel surprised if an observer accustomed to scrutinise the animal world so closely feels sceptical on the subject of "instinct." That notion is all very well for *literateurs*, lawyers, divines, or poets, who dabble a little in zoology, or for mere closet book-worms, who only catch a faint reflection of facts. But the naturalist of the field and the forest, though he recognises *instincts* in the lower animals, as in man himself, can but smile at "*instinct*," viewed as a mysterious entity, antithetically opposed to reason and supposed to act as its substitute in "our poor relations." The mutual helpfulness of ants is the more significant since, amongst social mammalia and birds, the tribe generally attack and put to death any of their number that suffers from an accident. The author gives two more instances of reason in ants. "I once saw a wide column trying to pass along a crumbling, nearly perpendicular slope. They would have got very slowly over and many of them would have fallen, but a number having secured their hold and reaching to each other, remained stationary, and over them the main column passed. Another time they were crossing a water-course along a small branch, not thicker than a goose-quill. They widened this natural bridge to three times its width by a number of ants clinging to it and to each other on each side, over which the column passed three or four abreast; whereas, excepting for this expedient, they would have had to pass over in single file and triple the time would have been consumed." In face of such facts the author asks—"Can it be contended that such insects are not able to determine by reasoning powers which is the best way of doing a thing, or that their actions are not guided by thought and reflection?" This view is much strengthened by the fact that the cerebral ganglia are more developed in ants than in any other insect, and that in all the Hymenoptera, at the head of which they stand, they are many times larger than in the less intelligent orders, such as beetles, or, we might add, than in those short-lived emblems of immortality, the butterflies.

Again, "amongst the ants of Central America, I place the *Eciton* as the first in intelligence, and as such, at the head of the Articulata. Wasps and bees come next, and then others of the Hymenoptera. Between ants and the lower forms of insects there is a greater difference in reasoning powers than there is between man and the lowest mammalian. A recent writer (Houzeau) has augured that of all animals ants approach nearest to man in their social condition. Perhaps if we could learn their wonderful language we should find that even in their mental condition they also rank next to humanity."

As regards their social condition ants differ from us in having successfully established communism. At the present day all the social Hymenoptera must be viewed with intense interest on account of their working-order or neuters. These, as is well known, are females whose normal development has been checked. Are we to assume that "once upon a time" a woman's rights movement sprung up in bee-hives and ant-hills, which ended in reducing the males to a very unimportant position, and in limiting the number of the fully developed females? Are we to expect that the "strong minded" ladies who are now arising among us are the forerunners of a "neuter" order, and the heralds of a corresponding change in human society?

"The Hymenoptera standing at the head of the Articulata," resumes our author, "and the Mammalia at the head of the Vertebrata, it is curious to mark how in zoological history the appearance and development of these two orders (culminating, the one in the ants, and the other in the primates) run parallel. The Hymenoptera and the Mammalia both make their first appearance early in the secondary period, and it is not until the commencement of the tertiary epoch that ants and monkeys appear upon the scene."

Just as in a chain of mountains the second highest peak is often far remote from the culminating point, so it is in the upheaval of the animal world to reason. The position of a being in the zoological series, or its proximity in structure to man, bears no relation to its degree of intelligence.

Warm as is Mr. Belt's interest in ants in general, and the *Eciton* in particular, he does not overlook the fact that to man they are a great nuisance. Their habits of biting off the leaves of trees, and of fostering and defending such vermin as plant-lice, are, from our point of view, highly objectionable. It is, therefore, a fortunate circumstance that carbolic acid and corrosive sublimate afford us the means of putting a stop to their depredations. Mr. Belt's experiments with reference to this subject are well worth the attention of tropical agriculturists.

The great bulk of our author's observations on animals and plants have been made, as the title-page informs us, "in reference to the theory of evolution of living forms,"—in other words, to the views popularly included under the name Darwinism. These views can scarcely be said to have met with fair treatment. They have been dolefully groaned over by certain "grave and reverend," if not very "potent seigniors," on account of their supposed "questionable tendencies," almost in the very words applied in the days of Galileo to the heliocentric theory in astronomy. They have been sneered at by witling gallants by whom the hint of kinship with monkeys was felt as an "owre true joke." They have been "gushed" over in the daily press by leader writers and special correspondents whose conceptions of the subject were of the haziest. The hostile critics of the evolution theory have been, for the most part, not naturalists but outsiders, incapabable of entering into the full meaning of the evidence. To take a case strictly analogous, what should we think of a lawyer who in a difficult and complicated matter should give a professional opinion founded on documents drawn up in a language with which he had but a very slight acquaintance? "Theories," says M. Dumas, "are like crutches; to judge of their value we must take them and try to walk with them." This is what Mr. Belt does, and all who candidly read his book must concede that the doctrine of evolution throws a welcome light upon many abstruse phenomena, and brings into organic connection facts which previously lay scattered in hopeless confusion. Let us take for example the phenomenon of mimetism—an unhappily chosen name—of which our author gives some interesting instances.

A certain animal species is often found to show a superficial, but still striking and deceptive, resemblance to some other species, generally of a totally distinct group; to some vegetable product, or even to a fragment of lifeless matter. Instances of this are the "walking leaves," the moss insect, discovered and figured by the author, which closely simulates a few filaments of moss lying on the ground; the mimetic bug (*Spiniger luteicornis*), which in form, in the colouration of every part, and in its very movements mimics the hornet (*Priocnemis*). This simulation, of course involuntary, enables the insect either to elude its enemies or to secure its prey. Thus the bug above mentioned might fall an easy victim to many birds and insects which would hesitate before attacking a hornet. Hence the bug owes its safety to its resemblance to the hornet. There is, again, a small spider which closely simulates a black, stinging ant. Spiders are greatly sought after and eagerly devoured by birds, whilst stinging ants are little relished. The Heliconii, a group of butterflies very largely developed in the West Indies and in Central America, have in all probability an offensive flavour. Birds, monkeys, and spiders avoid or reject them. There are other butterflies, belonging to perfectly distinct groups, which closely simulate the Heliconii, and thus escape the beaks of birds and the attention of spiders. The advocates of evolution explain this mimetism by supposing that, *e.g.*, a bug by some accidental variation from the normal structure of its congeners received a slight resemblance to a hornet. Its posterity, to whom this resemblance was transmitted, enjoyed an advantage in the struggle for existence over bugs which had remained true to the pristine type. Those of them in which the likeness to the hornet was most pronounced would, again, escape best from their enemies, and would thus have the greatest chance of becoming the progenitors of the next generation. The opponents of evolution have no way of accounting for mimetism beyond asserting that certain species were, for their protection, arbitrarily and *ab initio* endowed with these resemblances,—a most unsatisfactory explanation.

The same doctrine throws light on the difficulties often experienced in introducing foreign plants into any country. Thus the orange and the citron, in Central America, are very much more exposed to the attacks of *Ecitons* than any native vegetation. The reason is very simple:—"Through long ages the trees and the ants of tropical America have been modified together. Varieties of plants that arose unsuitable for the ants have had an immense advantage over others that were more suitable, and thus—through time—every indigenous tree that has survived has done so because it has had originally, or has acquired, some protection against the great destroyers. The leaf-cutting ants are confined to tropical America, and we can easily understand that trees and vegetables introduced from foreign lands, where these ants are unknown, could not have acquired—except accidentally and without reference to the ants—any protection against them."

If we reject the Darwinian view we should naturally infer that in any country foreign trees would enjoy an immunity from indigenous depredators, instead of being, as they are, especially singled out for attack. It is a curious fact that the leaf-cutting ants form, with the vegetable matter they thus carry off, manure-heaps, on which they cultivate minute fungi for the food of their larvæ.

With regard to the origin of species we extract the following interesting passage:—"The great mortality among the insects of Chontales, in 1872, has some bearing on the origin of species, for in times of such great epidemics we may suspect that the gradations that connect extreme forms of the same species may become extinct. Darwin has shown how very slight differences in the colour of the skin and hair are sometimes correlated with great immunity from certain diseases, from the action of some vegetable poisons and the attacks of certain parasites. Any variety of species of insects that could withstand better than others these great and probably periodical epidemics would certainly obtain a great advantage over those not so protected, and thus the survival of one form and the extinction of another might be brought about. We see two species of the same genus, as in many insects, differing but little from each other, yet quite distinct, and we ask why—if these have descended from one parent form—do not the innumerable gradations that must have connected them exist also? There is but one answer:—We are ignorant what characters are of essential value to each species; we do not know why white terriers are more subject than darker-coloured ones to the attacks of the fatal distemper; why yellow-fleshed peaches in America suffer more from diseases than the white-fleshed varieties; why white chickens are most liable to the *gapes;* or why silkworms which produce white cocoons are not attacked by fungus so much as those which produce yellow cocoons. Yet in all these cases, and many others, it has been shown that immunity from disease is correlated with some slight difference in colour or structure; but as to the cause of that immunity we are entirely ignorant."

In the following passage the author leads up to that phase of Darwinism of which the political economists have been making use:—"It was this constant struggle between the different tribes that weeded out the weak and indolent, and preserved the strong and enterprising; just as among many of the lower animals the stronger kill off the weaker, and the result is the improvement of the race."

Many persons in these days talk glibly about the "battle of life" and the "survival of the fittest," and the improvement of the race. But the question may arise—Who are the fittest? If we look at the vegetable world we find that the species precious to us for food, medicine, or clothing, and the kinds which delight our senses with the grace of their shapes, the beauty of their colours, or the delicacy of their odours, are precisely *not* the forms which would come out victorious from the struggle for existence. Were it not for man's constant intervention, the vine and the wheat, the rose and the carnation, would soon succumb to a tribe of weeds as devoid of utility as of beauty. Further, when man takes in hand to improve any race, his first step is to stamp out the struggle for existence, whether between individuals of such race or between the race itself and other species. If we examine the case of a turnip-field we find that the number of plants is strictly proportioned to the extent of the land, and that an unrelenting war is waged against all weeds. Were the struggle for existence permitted to rage unchecked we should certainly find some of the turnips larger than others, whether in virtue of more favourable circumstances or of more intense vitality in the seed. But the yield from the whole plot would be trifling, and no root would reach the dimensions attained where every plant finds a sufficiency of room and of nutriment. Perhaps, in like manner, the men most valuable to the world—the discoverers and inventors—are not those who win the ordinary prizes of life. Perhaps society or its rulers may one day find it necessary to take for a model the farmer's management of his turnip-field.

We can do no more than briefly call attention to the author's view of cyclones. From these terrific manifestations of force down to the eddy of dust which we often see crossing a road or a common, we have, according to Mr. Belt, one and the same phenomenon, differing merely in degree. Hence he recommends a careful study of these small dust-whirlwinds, as calculated to throw light upon the origin of cyclones. His own theory, first advanced in 1857, in a paper read before the Philosophical Institute of Victoria, is that the particles of air next the surface do not always rise immediately they are heated, but that they often remain and form a stratum of rarefied air next the surface, which is in a state of unstable equilibrium. This continues until the heated strata are able, at some point where the ground favours a greater accumulation of heat, to break through the overlying strata of air and force their way upward. An opening once made, the whole of the heated air moves toward it, and is drained off, the heavier layers sinking down and pressing it out. That hot air does not always immediately rise is proved by the hot winds of Australia, which blow from the heated interior towards the cooler south, instead of rising directly upwards.

In conclusion, we feel bound to give this book our most cordial recommendation. Few men possessing any degree of scientific culture will be able to read it without deriving both pleasure and profit, or will refuse to join us in the wish that this may not be Mr. Belt's last appearance before the public. It is no idle compliment to say that if he were a man of leisure, instead of a man of bustle and business, he would prove a worthy rival of Agassiz and of Humboldt.

V. ANNUAL INTERNATIONAL EXHIBITIONS.

By Fred. Chas. Danvers, Assoc. Inst. C.E., &c.

THE undoubted success which attended the two great International Exhibitions of 1851 and 1862 were unmistakable evidences of the popularity of those institutions, and the public, by the support they accorded to them, testified plainly enough to the correctness of the judgment which allowed a decade to elapse between the two events. Another similar occurrence in 1871 or 1872 would, no doubt, also have proved a success, notwithstanding that intermediate exhibitions elsewhere had, to some extent, anticipated the results which such an institution would have achieved. Nothing could be more advantageous than the establishment of a decennial exhibition of all nations, for the purpose of exhibiting the advances made in science during each period of ten years; but when the example must needs be followed by France, Italy, Germany, Russia, America, and probably other nations also, the Exhibition necessarily becomes one of almost annual occurrence, and the strain upon manufacturers becomes too great for endurance, and it soon manifested itself that such Exhibitions were degenerating into huge advertising affairs, and they were treated in just that light by manufacturers in general. Hence it was clear that the days of huge International Exhibitions were numbered, and that it would be impossible to extend their existence for any further lengthened period.

Whether it was from an appreciation of this fact, or from other causes, that led to their abandonment in this country, we are unable to state with any certainty; but on the 23rd of July, 1869, their death-warrant was signed, so far as this country is concerned, by the issue of an advertisement by Her Majesty's Commissioners for the Exhibition of 1851, wherein the public was informed "that the first of a series of Annual International Exhibitions, of selected works of fine and industrial Art," would be opened in London, at South Kensington, on Monday, the 1st of May, 1871. It was then contemplated that these Annual Exhibitions should be devoted each to certain classes only of industry and fine art, and it was so arranged that within a cycle of seven years all the principal arts and manufactures of the world would have been illustrated in them.

Before entering farther into an account of those Exhibitions that have hitherto been held, it is right that we should state that, prior to the issue of the advertisement above referred to, the whole question of Annual International Exhibitions was fairly laid before the leading representatives of Trade in London, and their opinions were invited as to the probable success of such Exhibitions. We are informed by one of the gentlemen so consulted that the unanimous verdict of the London Trade was that such Exhibitions not only could not succeed, but that they would be mere superfluities; that similar exhibitions, only on a far more extensive scale than could be achieved at South Kensington in the manner proposed, already existed, and were perennial, in all the leading thoroughfares of London; and that a person wishing to become acquainted with any particular branch of manufacture could do so, far more successfully and speedily, by visiting the show-rooms of a West End tradesman than by an inspection of anything that his branch of trade collectively would be likely to exhibit.

Anyone who has been a studious visitor to the Annual Exhibitions already held will be able to bear out completely the views expressed above. These Exhibitions have clearly not commended themselves to manufacturers generally in this country, whilst foreign nations have certainly been but very imperfectly represented on every occasion, although perhaps some exception may be made as regards the French *Annexe*, but then, as must have been apparent to all, the French Exhibition has not generally been devoted to the special classes of objects for which each year's exhibition was supposed to be devoted. But, independently of this. the French *Annexe* has, in a great measure, been the means of bringing these Annual Exhibitions to an untimely end. By this remark we do not mean to imply that there was anything in the principle or manner of conducting these Exhibitions that rendered their continuance even desirable; on the contrary, we were from the first impressed with a conviction that their ultimate failure was inevitable, but we were, perhaps, hardly prepared for their meeting with so speedy a dissolution. It appears that the French Government was induced to go to the expense of erecting its own *Annexe* at South Kensington, upon the distinct understanding that the exhibitors therein should be permitted to sell their goods, thus converting that part of the Exhibition into a bazaar or shop, whilst in other parts the exhibitors were often prohibited from even putting a person in charge of their several exhibits. From the reports on the 1871 Exhibition, published in Paris, we learn that in that year the articles sold in the French *Annexe* during the Exhibition were valued at over £20,000. This proceeding on the part of the Commissioners had, of course, the effect of handicapping all other exhibitors besides the French, which raised a storm of indignation, especially amongst the English exhibitors, which the Commissioners were unable to withstand; indeed many manufacturers positively refused to exhibit any further unless the odious distinction were withdrawn, and that either all or none in the Exhibition should be allowed to convert their stalls into shops. In consequence of the firm stand made by the English trade representatives an attempt was made to prohibit the selling license to the French exhibitors, and the consequence of this was that the French Court was not opened at all last year. This year it is again accessible to the public, and purchases may be made as freely as ever; for notwithstanding the prohibition against the removal of goods until after the close of the Exhibition, we are aware of one instance, at least, in which the delivery of goods purchased in the French Court has already been effected.

The inevitable consequence of this course of proceeding on the part of the Commissioners must, under any circumstances, have led to the early collapse of these Annual Exhibitions; but we understand that, besides this, other influences have made themselves felt which have induced the Commissioners to declare that this year's Exhibition shall be the last. The fact is, we believe, that these Exhibitions are not attractive enough to the public, and the necessary consequence is that they do not pay. In other words, these Exhibitions are not popular, and no better proof could be desired of the indubitable fact that they are not only not required, but that they are evidently looked upon as unnecessary *amusements* for the London public.

Looking upon these Exhibitions as Institutions for the Advancement of Knowledge, we think that the small attractiveness which they present to the general public is a sufficient condemnation of them from that point of view. As places of amusement they fail, because the London public is sufficiently educated to know how to discern between what is excellent and what is worthless. As Industrial Exhibitions these annual institutions have lost their hold on the public faith, and they have come to be looked upon more as bazaars than as International Exhibitions in the highest sense. Looking at these Exhibitions from a "South Kensington" point of view,—that is, as media of instruction to the public,—we believe that they might be made to pay, but then an entirely different arrangement to the present must be made for that purpose. Instead of inviting manufacturers to exhibit their goods at their own cost,—which can but end in an imperfect representation after all,—three or four manufactories might be exhibited in their most entire completeness, and visitors should be allowed to purchase and carry away any articles they may have seen manufactured. In order to carry out such a programme the manufacture must be complete in all its details; but for the laying down of the necessary plant and machinery the Commissioners would, of course, have in the first instance to bear all expenses, and perhaps even pay people to set up their factories within the Exhibition; but in all cases the manufactory should be complete, and the Exhibition should not only consist of a display of manufactured articles. With what interest would the blowing of a retort of Bessemer steel be viewed by the fair inhabitants of South Kensington,—at a safe distance from the sparks, and viewed of course through a spectroscope,—and with what delight would the young men of London hasten to see a huge casting run direct from the cupola, or a massive bloom of iron writhing under the thud strokes of a 50-ton steam-hammer? We were fortunate enough to see some of the glass manufactured for the Exhibition of 1851, and can testify to the attraction which such a display would yield to the London public; whilst the manipulation of glass in its finer forms—such as in the manufacture of wine-glasses, decanters, or tumblers, and the subsequent processes of their cutting and ornamentation—would contribute no slight entertainment to the sight-seeing people of London. We are perfectly well aware that these sights are all to be seen within the great city of London itself, but they are not so accessible to the general public as the display of the manufactured articles themselves. The only question for the Commissioners to consider is whether such displays could safely be carried out on the present site. The public have now had over twenty years of exhibitions of manufactured articles, and it appears that the time has now abundantly arrived when the process of manufacture should also be exhibited more fully than has hitherto been attempted.

We refrain from entering into any further details on this subject on the present occasion, but having thrown out the idea in a somewhat vague way, perhaps, we proceed now to review, as briefly as possible, what have been the results of the past four Annual Exhibitions, including, of course, the current one which has not yet closed its doors upon the unappreciating public.

The Exhibition of 1871 was confined mainly to three classes, viz., fine arts, pottery, and woollen and worsted fabrics, together with machinery employed in the manufacture of the two latter classes. Besides these, however, there were also exhibited educational appliances and instruments, scientific inventions and new discoveries, and horticulture. Amongst the machinery employed in the manufacture of pottery there were brick- and tile-making machines, clay-crushers, pug-mills, pottery wheels, pipe-making machines, stone-breaking machines, whilst in another part of the building was exhibited every conceivable variety of finished products of the potter's art, from the exquisitely finished designs of Wedgwood, Minton, and Daniell, to a ginger-beer bottle and tobacco-pipe. Amongst the machinery for woollen and worsted manufacture were exhibited various power looms, combing machines, balling machines, carpet-weaving machines, &c., &c., whilst the manufactured articles were also exhibited in endless variety. It would be out of place, upon the present occasion, to enter into detail regarding what was exhibited so far back as 1871, but it may be generally remarked that, whilst some of the exhibits were decidedly novel, many were of an uncertain age, and the Exhibition generally could not be looked upon as in any way representing the fullest advancement that had been developed in the special classes exhibited. Scientific inventions represented upon that occasion formed the subject of an article in the "Quarterly Journal of Science" in the same year.

The second of the series of annual International Exhibitions was opened on the 1st of May, 1872. As in the former year, this Exhibition consisted of three main divisions, viz., fine arts, manufactures, and recent scientific inventions and new discoveries. The leading manufactures represented on this occasion were cotton, cotton fabrics, jewellery, paper, stationery, and printing, whilst musical instruments of all kinds, and acoustic apparatus, were also represented. Paper formed the principal topic of exhibition, and it was dealt with at some length, at the time, in a special separate article. Notwithstanding the great importance of the classes selected for exhibition, it cannot be said that they were well represented so far as the mechanical part of the Exhibition was concerned, although there was a fair display of manufactured goods. As regards scientific exhibits more care was displayed by the Commissioners in the selection of objects, so that fewer trivial articles found their way in than was the case in 1871.

Class II. in the Exhibition of 1873 comprised silk and velvet fabrics, steel and cutlery, surgical instruments, carriages not connected with either railways or tramways, substances used as food, and, finally, cooking and its science. One noticeable feature in this Exhibition was a falling off in the machinery department, which may perhaps be partially explained by the existence of a formidable rival at Vienna, where, it may be presumed, most articles worthy of being exhibited were sent, in preference to South Kensington. This year the industrial arts represented at South Kensington include leather, hand- and machine-made lace, civil engineering, architectural and building contrivances, sanitary apparatus and constructions, cement and plaster work, heating by all methods and kinds of fuel, bookbinding, and foreign wines. The mechanical exhibits are—machinery for lace, leather, bookbinding, civil engineering and building, and such as are included under the head of recent Scientific Inventions.

At best, the present Exhibition cannot be said to be in any way an improvement upon its predecessors; in some of the classes it is very poorly represented, and upon the whole it decidedly lacks interest. Indeed, a visit to South Kensington is quite sufficient to prove, to the most casual observer, that these annual exhibitions are gradually dying out from natural causes.

The great International Exhibitions have grown at so rapid a rate that it is very clear that they could not long be continued, upon their original basis, in consequence of the vastness of the buildings required for their reception. But in endeavouring to limit their proportions by spreading them over seven years, their interest has also diminished in proportion, not only to the visitor, but equally so to the exhibitor, and hence the cause of their failure. In a recent letter to the "Times" newspaper (Tuesday, June 9), Dr. Forbes Watson entered in some length upon the great question of Exhibitions, and, while admitting the failure of the present organisation, he recommends that instead of endeavouring to make them popular, class exhibitions should continue to be held, under a revised system of arrangement and management, more in the interests of respective trades than of an unsympathising public. With regard to the present system he argues that the "conditions under which they occur, the brevity of their existence, the multiplicity of similar objects, the impossibility of a systematic arrangement, make it all but impossible that any profit should be derived from them except to those already acquainted with the subject. International Exhibitions," he goes on to state, "might be utilised less for the purpose of increasing the number of people possessed of technical education, than for raising the level of knowledge among the classes already possessed of the fullest information regarding each of the subjects represented at the Exhibition." And this information once acquired should, it is further suggested, be rendered permanently available to the country by being embodied in museums.

Theoretically, this suggestion looks very well upon paper, but practically we very much doubt the possibility of its being carried out. The true advancement of manufacturing industry will, we confidently predict, never be demonstrated in such exhibitions, for in most trades there are so many secrets—each manufacturer possessing certain knowledge of his art which is not patented or otherwise divulged to his competitors in trade—that it is impossible to hope that the ultimate stage of advancement and knowledge will ever be represented in public exhibitions. Indeed, it is to these exhibitions chiefly that we owe the vast amount of foreign competition in manufactures, not only abroad, but even in our own markets.

Whatever may be the next stage of International Exhibitions, it is to be hoped that a reasonable time will be permitted to elapse before anything else of the kind is attempted; indeed, it seems necessary that such should be the case, for, the present annual series having come to a premature end, a fresh system and organisation will necessarily be required before anything new can be attempted.

VI. THE IOWA AND ILLINOIS TORNADO OF MAY 22, 1873.

By JAMES MACKINTOSH, M.A.

THIS tornado could not—by its destructive effects upon trees, buildings, &c.—be traced further back than Section 35, Warren Township, Keokuk Co., Iowa. At the point where the destruction commenced, the South Skunk river bends southward, and then again to the east, thus half inclosing a low level area of about 1 mile in length by ½ a mile in breadth. This bottom land is surrounded by bluffs about 70 feet in height on nearly all sides, the river flowing close to the bluff on the S.W. It was at the north-east edge of this natural amphitheatre that the tornado first attained force sufficient to demolish fences. It is difficult and unnecessary to determine its starting-point: there is, however, no doubt of the fact that it first attained to desolating violence on the farm of W. W. Morrow, situated half-way up the bluff. Its previous history was only that of a thunderstorm, accompanied, perhaps, by an unusual tumult and whirling of the clouds. In tracing its development and progress, therefore, I probably labour under no disadvantages which do not necessarily attach to the history of all such meteors, except those arising from the circumstance that the tornado was not at any point of its progress witnessed by a skilful meteorologist.

Mr. Morrow testified that neither he nor any of his people noticed any funnel-shaped appearance or tongue of cloud approaching the earth. There was a strong wind for a minute, but the destructive gust appeared to be instantaneous. A smart shower of hail followed the gust. A whirling of the clouds was observed several minutes before the wind. A little lightning was seen. The storm travelled E.N.E. over Andrew Surber's farm, blowing down fences with a S.W. wind. He saw the clouds whirling like a great wheel, 35 degrees in width, before the storm, but did not notice any funnel appearance. Some hail fell with the wind, and a considerable shower of rain after it.

John Malcum, Section 30, Lancaster Township, was 1 mile south of tornado when it occurred. Heard a roaring like steady thunder in the west about a quarter of an hour before the storm came. Saw no lightning. A cloud covered the western, the northern, and north-eastern portion of the sky. It extended somewhat beyond the zenith. The rest of the sky was clear. Saw a mass of clouds whirling contrary to the hands of a watch. The whirling mass appeared to be about 60 degrees high when directly opposite. A smart shower fell some time after the tornado.

On Malcum's farm the roof of a stable was blown to the south-east. This was the first damage done by a north-west wind. Two hundred yards south of the stable a fence was blown toward the north-west and north. The storm, after becoming destructive, had travelled 1½ miles before it developed force sufficient to commit destruction by a north-west and south-east wind.

The breadth of fences thrown down on the farm of T. Dawson, Section 31, Lancaster Township, was about 60 rods. The outhouses, &c., were damaged. A cultivator weighing about 200 lbs. was carried or dragged 30 feet; it presented to the wind a surface of not more than 3 square feet. If it was carried, the lifting force of the wind must have been between 60 and 70 lbs. per square foot. The ground showed no signs of its having been dragged.

M. Williams, lawyer, Section 32, Lancaster Township. watched the storm as it approached for about one hour; it was a few minutes after 2 P.M. A cloud rose in the west, which, stretching to the north-west, presented the appearance of heavy rain. Previous to the approach of this cloud the sky was nearly clear. The wind during the day was southerly. About twenty-five minutes after the tornado the wind was again from the south-west. The storm-cloud did not extend far past the zenith to the south. Saw the funnel distinctly. It alternately lengthened and contracted, rose and fell. When it contracted, it appeared as if the narrow point next the earth was cut off, leaving the lower end broader. At times the upper end appeared to reach the overhanging clouds, and at times to be not so high. It was of a dark blue colour when 250 yards distant; when 300 yards distant it subtended an angle of about 75°; the angle subtended by the top of it at that distance was about 55°. It had a zigzag motion. Half an hour previous to the tornado there was incessant lightning in the north-west. Heard no thunder. There was no lightning in the tornado. A little rain and hail fell just before the tornado, and a smart rain-shower about twenty minutes after it. Heard that to the northward there was a terrific storm of rain and hail, accompanied with thunder and lightning. The wind was south generally during the day. As the tornado approached the wind changed to a little east of south. Saw the dark funnel strike the ground on my farm. Saw it whirling contrary to the hands of a watch. This witness was stationed about 25 yards south of the storm-centre when nearest to it. The fences were generally thrown toward the centre on either side, but where the dark cloud touched they were carried away for a space 60 yards wide. We have here the first evidence of the dark cloud touching the earth in perfect funnel-form; but its touch is yet only temporary: it proceeds with a wavy, zigzag, circular-pendulum motion. By-and-bye its tread will make the earth tremble.

The storm traversed Jones's farm, throwing down fences, until it struck the Wolfden school-house, which lay near its centre. The school was in session when the tornado struck it.

Richard Weller, teacher, testified that this occurred at 2.15 P.M. precisely. This time is valuable, and I have adopted it as one of the data for calculating the velocity of the storm. The school-house was moved, with the children and teacher in it, to the east, the north end 30 feet, the south end 20 feet. It was not overturned. The windows, roof, &c., were much damaged, but there were no evidences of explosive forces. The weight of the building was given by Mr. Williams as probably 30,000 lbs. The surface exposed was 360 square feet, besides the slanting roof. The slant of the roof was about 45°. The foundation was stone. It became very dark as the tornado struck. After leaving the school-house, which is situated in a slight ravine-like depression, the fury of the tornado abated somewhat: hence, although it was nearly central over the hamlet of Hayesville, the frail houses were scarcely touched.

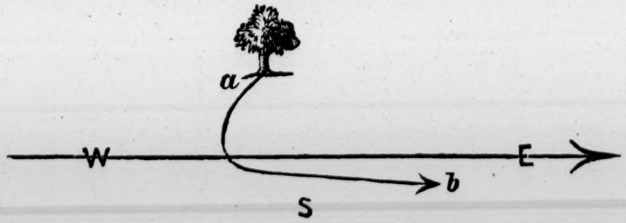
The storm up to this point had been travelling E.N.E. Since leaving South Skunk river it had been traversing a rolling prairie, with numerous sloughs, as they are called, but nothing like a water-course. It struck Troublesome Creek, the banks of which are well wooded. No sooner did it do so than it increased greatly in power, changed its path temporarily to due east, and developed the phenomena of two or more funnels or branches of a funnel. Down in the hollow, among the trees, stood the house of widow Jacobs. It was completely demolished, but without signs of explosion. The storm-traces are already in great part obliterated, and a new house rebuilt. The path of destruction was 200 yards wide at this point, and the general aspect of the fallen trees within this limit presented all the appearances of a complete cyclone revolving contrary to the hands of a watch, although nothing particularly worthy of notice presented itself. About a quarter of a mile from the main track to the south, a swath, about 50 yards wide, was cut through the fences by a south-west wind. This swath appeared to curve towards the main storm-path, but it was not possible to follow it until it reached it, because of the sparseness of the fences, and because there had everywhere on that side of the storm been a strong south-west wind, and this swath was merely exceptionally strong.

The storm-centre next traversed the Grout Farm, now occupied by Samuel Brunt, and passed about 100 yards to the north of the village of Lancaster. Here its operations became more interesting.

Samuel Brunt heard it roaring a long time before it arrived; as it approached saw two funnels distinctly: their summits were lost in the overhanging mass of dark cloud. Saw funnel on the south side, which was the smaller, swing around in a half-circle and join the larger one. The funnel had a pendulum motion. When it struck the ground it seemed to smoke, the smoke surging up like spray upon a wave-beaten rock. The wind felt cold as it passed. Saw lightning during tornado. The breadth of the dark apex of the main tornado, where it touched the ground, appeared to be about 100 feet: there the wheat was mown as with a scythe.

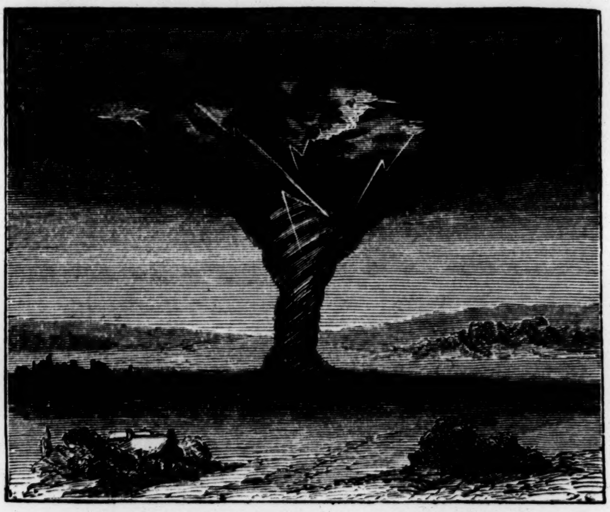
The breadth of the part of the storm of sufficient power to throw down fences was here 200 yards. The fences on the north side were blown south, those on the south side north, while along the centre everything was carried east with the storm. An apple tree, 7 inches in diameter, which had stood on the north side of the centre, was carried first 14 yards south, with a little westing, then round in a regular curve 24 yards toward due east, and then due east for 70 yards. A beam, 2 ins. × 4 ins. × 14 feet., and weighing 25 lbs., was driven into the ground 3 feet 9 inches at an angle of 35°, after having been carried 35 yards from the barn roof. The following is a sketch of the path of the apple tree: it stood at *a*, and was carried to *b*.

FIG. 8.



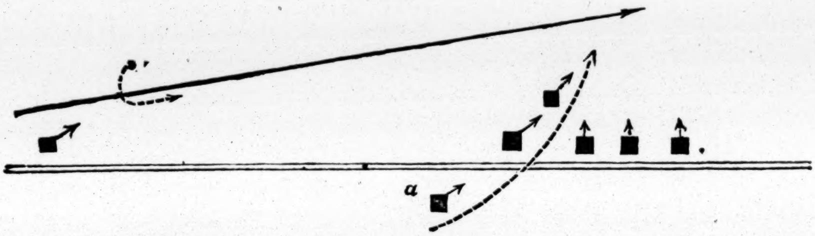
Fred. Tollman, Lancaster Village, was within the edge of the tornado. Was whirled like a top for 50 yards, and lodged against a fence. Observed it for more than fifteen minutes before it came. Saw trees twisting in the grove half a mile distant. Saw the funnel whirling contrary to the sun; its summit was lost in overhanging cloud. Thinks the upper cloud was also whirling. Saw only one funnel. Saw lightning flash up and down the funnel. Saw a tree thrown out from the top of the funnel about 1 foot in diameter. Top of funnel 60 degrees high when 70 yards off. There were two funnels with the small ends together, thus, the upper one being the largest:—

Fig. 9.



The evidence for the village of Lancaster is somewhat discordant, or rather various. Some saw only one funnel; some two funnels, side by side; and others two funnels superimposed, with the small ends together. The discrepancies are, however, easily accounted for. As the cloud approached it grew very dark. The tornado doubtless changed its form rapidly. The observers took a glimpse at it, and ran to attend to their houses, or had to watch it under difficulties. Those who saw two funnels appear to have seen through the centre of what appeared to those at a greater distance as only one funnel with the larger end down. The evidence afforded by the ruins in the path of the storm gives no support whatever to the belief that there were two distinct whirlwinds. The two dark clouds touching the ground worked together in the strictest harmony in producing such effects as would be produced by one tornado whirling contrary to the hands of a watch. But, as already instanced, streaks of wind of unusual power curved in half-circles toward the centre at certain places. One of those streaks passed in a north-easterly direction through the town of Lancaster, while the main whirl was 100 yards to the north of it. This streak was at first only a few yards broad, but rapidly increased in width as it proceeded. It first unroofed a frail stable, without injuring the house beside it. It then increased in force, throwing down four or five houses, and unroofing as many more. The following shows the position of the houses and the directions in which they were blown:—

FIG. 10.



The long arrow denotes the main track; the curved arrow the streak mentioned; the short arrows show the direction of the destructive wind which threw down the various buildings. Between the building *a* and the main storm-path there is a space of 50 yards comparatively uninjured. The sketch does not pretend to be strictly accurate as to distances, but to give the relative positions of the houses.

Leaving Lancaster, the whirlwind travelled down the declivity toward North Skunk river in a direction somewhat east of north-east. It levelled the fences in its path, in the way already described, and which never varied from its commencement to its end. The house of widow Dogget, situated about a quarter of a mile south of the river, stands a little to the north-west of the storm-centre, at the commencement of the level bottom lands. Here two deep ravines—one from the south and one from the east—meet. Here the storm developed enormous power, smashing up the timber terribly. The roofs of the house and barn were carried south and somewhat west. The trees on the north side of the centre were thrown down toward the centre, some pointing south-west and south, but the majority south-east. On the south side of the centre they lay pointing north-east, north, and north-west. An oak tree, 12 feet in circumference at the base, was broken across 12 feet from the ground. At the bottom of the narrow, steep ravine, running east and west, trees were lying just as they fell, some pointing east and some west.

One quarter of a mile beyond Mrs. Dogget's house the tornado reached North Skunk river, which it then followed for over 2 miles, in a south-easterly direction, until it came to the southerly bend of the river, opposite Kohlhaus's saw-mill, when it suddenly turned to the north-east. The bottom lands on both sides of the river are here covered with tall timber, and through this timber the storm tore its way with resistless fury. All trees within a breadth of about 100 yards were either overturned or broken off and barked. The barking was evidently the result of three things:—

1. Many of the trees barked had been bent, so as to loosen the fibres of the wood. Such bending would infallibly loosen, and perhaps break, the bark.
2. The air was thick with missiles, which not only broke the bark, but sometimes penetrated the wood. I have seen a corn stump less than 2 inches in length sticking in the bark of a large tree which it had penetrated.
3. The peeling off of such loosened and broken bark would be a light task for such a tremendous blast. There was not the slightest evidence of electric action or of vapour explosion.

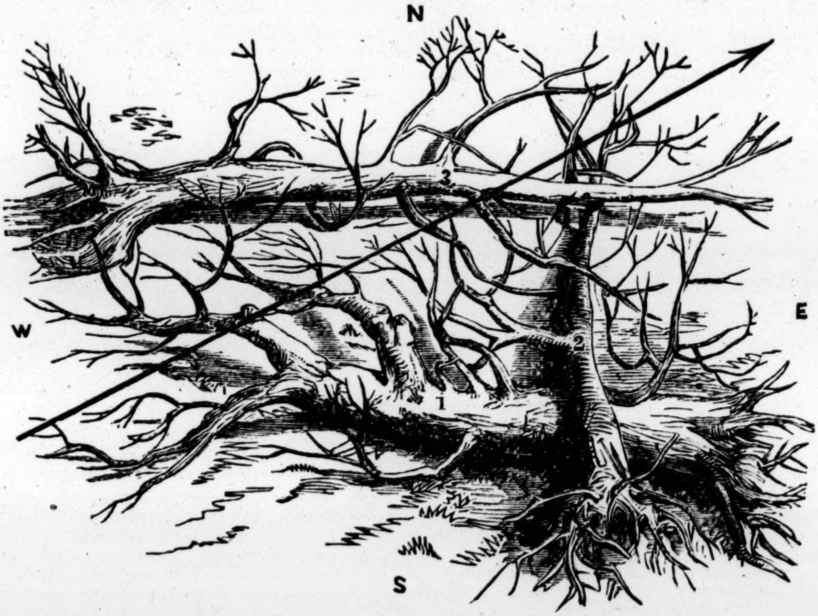
Broken trees had the bark torn off, both up and down, from the point of breakage. Trees half broken and bent to the ground were similarly stripped.

At the place of rupture the trees generally presented that broom appearance in which the supporters of the theory that electricity is the principal agent in the production of tornadoes have seen conclusive evidence of its truth. It will afterwards be shown, when this phenomenon becomes more common than could be expected on the soft soil bordering North Skunk river, where trees were more easily uprooted than broken, that this broom appearance is due to the excessive bending and straining of the fibres of the wood, and their rupture, in succession, from the exterior inwards.

The river, being impassable, rendered the examination of the general position of the fallen trees more difficult. Everything, however, corroborated the evidence already so abundantly adduced, that the tornado was a whirlwind of powerful centripetal tendency, circling contrary to the hands of a watch. The following arrangement of fallen trees was selected as being typical. It was found on the north side of the river, near the centre of the tornado.

No. 1 is a tree 3 feet in diameter, but much decayed, blown down from the E.S.E. No. 2 is a tree ½ foot in diameter, blown down S.S.E. No. 3 is a tree 2 feet in diameter, blown down from the W. No. 3 lies above No. 2, and No. 2 above No. 1. It occurred just where the storm left the river.

FIG. 11.

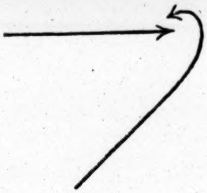


That the force of the storm was enormously increased immediately after reaching North Skunk river is proved by the greatly extended width of its path. At A. Dogget's and B. C. Moore's houses, three-quarters of a mile distant from the storm-centre, the out-buildings were damaged and the fences thrown down by a southerly wind. Mr. Dogget testified that the tornado appeared somewhat like two funnels with the smaller ends together, and that when apparently 3½ miles distant the column subtended an angle of about 25°. The houses of these gentlemen are situated on the summit of the bluffs facing the river, which are perhaps 200 feet high.

The house of Joseph Ash, situated on the face of the bluff, and distant from the river about half a mile, was blown to the S.S.W. Large trees were at this distance blown down in the ravines running to the river. Mr. Ash testified that the wind lasted a few minutes, and that it changed to the north-west after the passage of the tornado. A little hail fell before the storm, and a small shower of rain after it. Saw lightning and heard thunder. It grew cool as the storm passed.

The following represents the apparent direction of motion of the two funnels as they approached each other :—

FIG. 12.



The house and steam saw-mill of Joseph Kohlhaus stood directly in the path of the meteor, at the distance of a quarter of a mile from the river, on the north side.

The buildings stood upon the summit of a rising ground, about 30 feet high. Between it and the river is a half pool, half marsh. It was completely emptied of water. The breadth of the path of wholesale destruction was, upon the summit of the hill, 270 yards. The house stood 100 yards from the eastern and 170 yards from the western extremity of this path. The timbers and contents of this house were carried in a half-circle first to the north-west, then to the west, then south-west, then south, and finally to the north-east, the heavier articles being generally sifted out first, thus marking the way the ruins went.

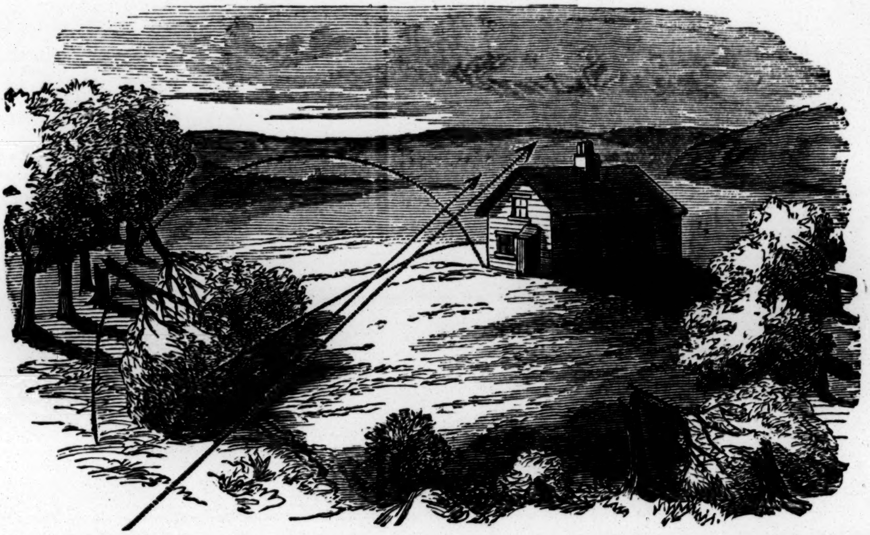
On the eastern edge of the path was an orchard, and on the western a wood. The trees in the orchard were blown down from the south-east and south; the trees in the wood from the north and north-west. Portions of the clothing from the house and shingles from the roof lay among the trees in the wood, or stuck among the branches. There were no signs of explosion, the doors and windows having been blown in. The inmates were all more or less injured. The width over which fences were blown down was here about three-quarters of a mile. An iron plough, weighing 200 lbs., was carried 40 yards. The sheet-iron chimney was carried 2 miles to the north-east. An iron sausage-machine, 6 inches by 8, and weighing 15 lbs., was blown away; part of it was found 1200 yards distant. The wheels of waggons were smashed, and the tyres twisted.

Fig. 13 is a representation of the effects of the whirlwind at this place.

After leaving the mill the storm ascended a hill some 200 feet in height, levelling the fences, but with evidently diminished violence.

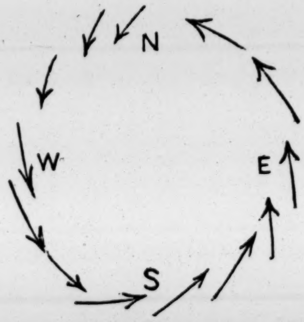
Passing over the top of the hill in a north-east direction, it struck Rock Creek, which here runs south, with a little easting. Immediately altering its course, it went straight up the creek for about half a mile, developing prodigious power. The large trees which lined the banks were torn and peeled and overthrown in promiscuous ruin. At a point where there is a small circular island, and a considerable amount of stagnant water around, the storm would appear to have stood still for a moment. Fig. 14. shows the position of the fallen trees at this point.

FIG. 13.



There were no trees on the island itself. There was no evidence whatsoever that the barking of the trees had been effected by electrical action or sudden evaporation. Every-thing tended to prove that the bark had been loosened and broken by the excessive bending of the trees and by flying missiles. One of the steers killed at this creek had an oak rail driven completely through its shoulders.

FIG. 14.



On reaching a slough which enters Rock Creek from the north-east the tornado followed it. Beside this slough and close to the creek was a small grove of young trees belonging to John Stein. This grove was completely carried away, nothing remaining except a few barkless twigs. At no point in its course did the storm develop greater energy than at this grove. Generally young saplings, over which the centre of the storm passed, were, although stripped of bark and twigs, left standing. Here the ground was whipped as bare as though the grove had been lashed with a whirlwind of fire. The tornado then passed between the houses of William Goeldern and John Stein, sweeping the fields, within the narrow path of its greatest violence, clean of grass, wheat, and corn stumps, while the ground was torn and furrowed by flying rails and trees. The rails and broken timber had been gathered from the fields; but John Stein assured me that they lay thickest along the centre of the storm. Along the sides of the path of greatest violence many rails were driven deeply into the soil, end foremost.

While the main whirlwind thus pursued the path described, there were smaller off-shoots or arms which played havoc on its south-east side. Such an arm cut a swath about 12 yards through Schild's orchard from south-west to north-east, the swath widening as it went. It was not possible to trace it until it reached the main storm, for reasons similar to those already given. It seems probable, however, that it joined it at the little island above mentioned, where the storm appears to have momentarily stood still. The relative positions favour such a surmise. This streak of strong south-west wind was a quarter of a mile distant from the centre of the main tornado.

A similar streak levelled the fences close to the house of John Stein for a width of 50 yards, while nearer the main tornado the fences remained standing. This streak, I surmise, joined the main storm at the grove above mentioned. A similar arm tore down the new barn of F. A. Latz, about a quarter of a mile farther on, without injuring weaker buildings close beside it. The path of this streak is said to have been very distinct among the fences until it joined the whirlwind near the house of Peter Marsh. The fences were, however, already restored.

George Star, three quarters of a mile south-east of the tornado, said that about 1 P.M., it commenced to thunder and lightning in the north-west. The storm advanced along the northern sky, and it lightened terribly there previously to the arrival of the tornado. A big cloud extended from south-west to north-east. It cleared up immediately after the tornado, both here and in the north. This witness lost eighteen head of cattle at Rock Creek. One was perforated by a rail.

John Marsh's house stood a little to the north-west of the centre of the storm. He watched it as it came directly toward him. It deflected a little from side to side, with a zig-zag motion. It turned and twisted like a screw in revolution. All the family were in the house, the house having no cellar. It became as dark as midnight. The windows and doors were blown in, in spite of resistance, and they knew no more until they found themselves lying in the slough, severely wounded.

The destruction at this house was most complete. The house was carried forward from its foundations bodily; but as it was going down a declivity toward a slough, it failed to strike the ground until it went to pieces. The heaviest timbers and the inhabitants were deposited in a slough, about 100 yards S.S.W. of where the house stood. One child was killed instantly, and Mrs. Marsh has since died. The fragments of the house were carried, first to the south-west, then in a curve to the south, the south-east, the east, and then along the centre of the storm to the north-east, the heavier articles sifting out as they went. I found ears of corn 200 yards to the south-west and south of the house, and a fragment of heavy wood 400 yards to S.S.W. Two cows and thirteen hogs were in a yard a little nearer the centre of the storm than the house. They were carried 100 yards to the south-east, and killed or fatally injured. A stone from the foundations of the house, weighing about 100 lbs., was said to have been carried about 100 yards south; but I could not find it. Sowing machine, cultivators, wagons, &c., were wholly carried away, and left not a wrack behind. The timber was generally reduced to the dimensions of fine fire-wood, and thickly strewn along the path of the storm to the north-east. The width over which fences were thrown down was here about half a mile.

Fig. 15 is a sketch of the path of the ruins of Marsh's house, *a a a* representing track of ruins of house, *b b* the centre of path.

A quarter of a mile to the north of Marsh's house stood the house, barn, &c., of M. Fuh. They were blown to the south-west, but without being carried away. The next house struck was that of M. E. Hamis, the storm-centre passing about 20 yards to the north-west of it. The fiercest of the storm was here only 100 yards wide, but fences were blown down for over 500 yards. The doors and windows of the house were driven in by the wind and the flying missiles, and immediately the house went to pieces. The house and out-houses were carried away, broken to small pieces, and deposited for a mile or two along the path of the storm. The trees around the house, which were not plucked out by the roots, had their tops and branches broken off and their bark stripped from them. The stripping of the bark was evidently due to the causes already assigned. The stripping was most complete on the south-west side of the trees. A fence 400 yards in length, and running east and west, was deprived of its boards, the posts still remaining in the ground. Where the storm-centre crossed it, the direction toward which the posts were leaning was intermediate. On the west of the centre the posts were leaning south, with a little easting, and on the east of the storm-centre they were leaning north, with a little westing.

FIG. 15

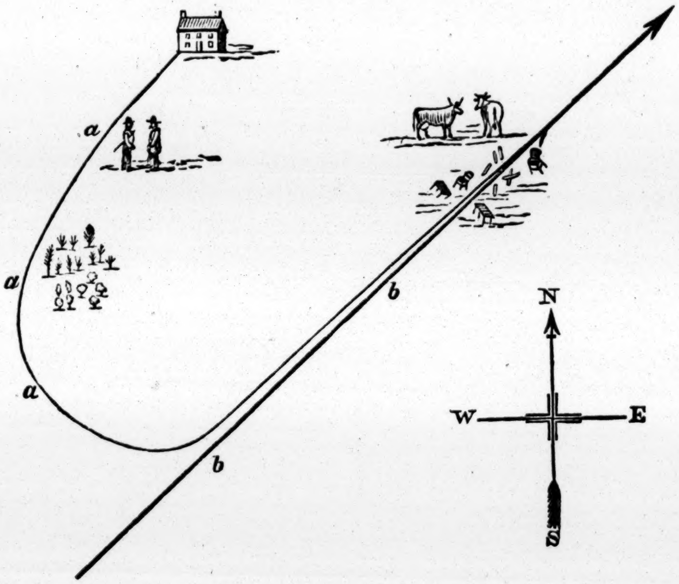
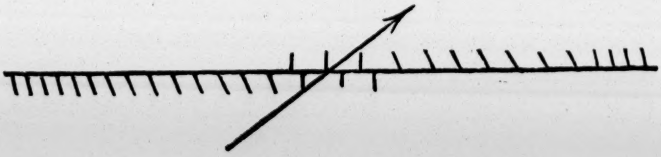


FIG. 16.

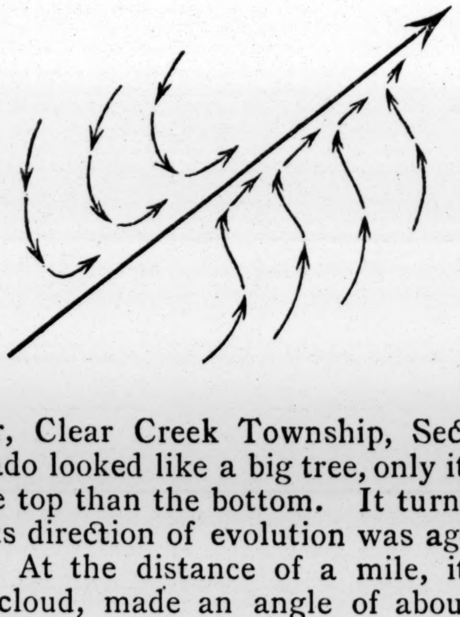


The above is something like the disposition of the posts along the line of the fence. The length of the fence thrown down east of the centre was about one-quarter greater than that thrown down on the west of it.

The corn-stalks in a contiguous corn-field were thus disposed :—Those on the south-east side of the centre curved around from pointing nearly due north to nearly due west. Those on the north-west side curved around from pointing nearly due south to nearly due east. Along the centre all pointed with the storm. This shows the direction of the last wind, strong enough to alter the position of the stalks. (See Fig. 17).

Matthias Linen, a quarter of a mile north-west of the edge of the storm, testified that it presented the appearance of a great column, reaching from the ground to the clouds, and whirling contrary to the sun. It seemed to remain almost still at some places, and then would dart forward. Hail 4 inches in diameter, very irregular in form, fell as the storm passed.

FIG. 17.

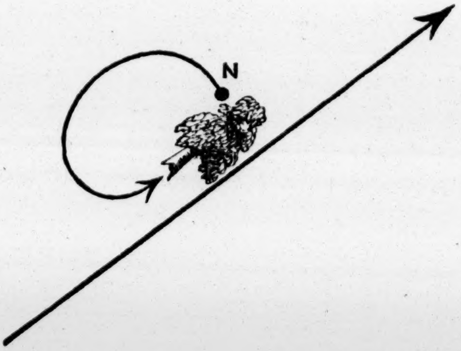


Paul Piffer, Clear Creek Township, Section 9, testified that the tornado looked like a big tree, only it was five times greater at the top than the bottom. It turned like a wheel in a mill. Its direction of evolution was against the hands of a watch. At the distance of a mile, its top, when it entered the cloud, made an angle of about 60°. Hail as large as pigeon's eggs fell before the storm, and it rained very hard after it. Saw lightning in the west previously.

Mr. Piffer's house stands about 70 yards to the north-west of the storm-centre. Its path is here about 200 yards wide. The arrangement of stalks in a corn-field was the same as that already given. The roof of the house was carried south. A stump-cutter, which was standing by the house, was carried—the iron portion 50 yards south, the wooden portion half a mile to E.S.E. Wheels which came within the reach of the storm were dashed to pieces, and the tyres twisted into all sorts of shapes. An oak tree, 3 inches in diameter, and which stood exactly in the storm-centre, was split by a fragment of a board 1 inch thick. The board was originally probably 6 inches broad and 8 feet long. Of the two small fragments remaining in the tree, the longer was only 17 inches in length. The board was driven into the tree from the south-west. The path of extreme violence, about fifty yards wide, was strongly marked in the grove of young oaks. They looked as if they had first been lashed against a pile of stones and then trailed in the mud. Portions of bark were struck off and the smaller branches shattered and peeled. This grove stands upon the edge of a steep declivity about 100 feet in height, at the bottom of which flows Clear Creek. Here is a circular hollow nearly enclosed by high bluffs, and within it the storm raged with demoniac fury, smashing trees of 4 feet in diameter to pieces.

The following instance was found on the opposite declivity, up which the storm raged with undiminished power:—

FIG. 18.



The tree stood at N originally. Its root was partly decayed, and it must have fallen with the first strong gust. The path which it travelled was cut out in the grass by its root. This path was 47 yards in length, and was nearly circular. It first moved to the north-west and then round in a curve, until it lay pointing to the north-east, with its top almost touching the spot where its root had formerly been. The tree stood to the north-west of the storm-centre, and was 2 feet in diameter.

Crossing the summit of the rising ground, which was thoroughly ploughed up, the storm traversed a wooded ravine, where for a width of fifty yards it deprived the young trees of their twigs and of much of their bark, besides throwing down the full grown.

The house of Nick Engledinger, Section 10, Clear Creek Township, stood about 100 yards from the south-east edge of the tornado. From any indications which the remains presented, the timbers must have first been carried north. Two persons were killed—one of them being torn to pieces.

A hog weighing 400 lbs. was carried one mile and a quarter in the line of the storm.

The house of Jacob Kœrth stood fifty yards within the north-west edge of the storm. The timbers went south. The people tried to prevent the wind from blowing in the doors and windows, and could not. The wind entered and blew the house asunder, leaving the floor in its proper position. Hogs weighing 300 lbs. were carried to the north-east across a ravine and deposited 300 yards away. A horse, a cow, and a bull were similarly carried 200 yards. Sheep were carried 400 yards. In addition to the accidents inseparable from such an aërial voyage, the bodies of the animals were driven full of pieces of wood. On this account the bodies of all animals which perished in the storm were burned.

A horse-power machine, partly wood, but chiefly iron, and weighing 2400 lbs., was pushed or carried six yards. It was resting on the ground, and was separate from all other objects. There were no marks upon it arising from violent collision with other bodies. It exposed a surface of about 2 square feet to the wind. It lay close to the ground. The master of this house was absent, and information, owing to the invalid condition of the inmates, hard to obtain.

The storm now turned somewhat more to the northward, traversed several fields, demolishing the fences, until it struck the house of R. F. Campbell, Lafayette Township, on the borders of Clear Creek Township. The exact position of this and the two immediately preceding houses was difficult to determine upon the map, because of its very defective condition, and because their owners could not tell me what section they were in.

The following is the appearance the vortex presented at the distance of 70 yards. There appears to be two incipient funnels, one on either side.

A post 8 feet in length, and driven into the soil 3½ feet, and 4 inches in diameter, was pulled out by the wind. It stood without attachment.

The width of the storm here is 160 yards. The house stood within 20 yards of the north-west edge. It was tilted up on its corner bodily, inmates, floor, and all, and deposited on its roof 17 yards to the south-west of its former position, and then went to pieces. There was no indication of explosion. The accompanying is a plan of the effects of the storm at this house:—

FIG. 19.

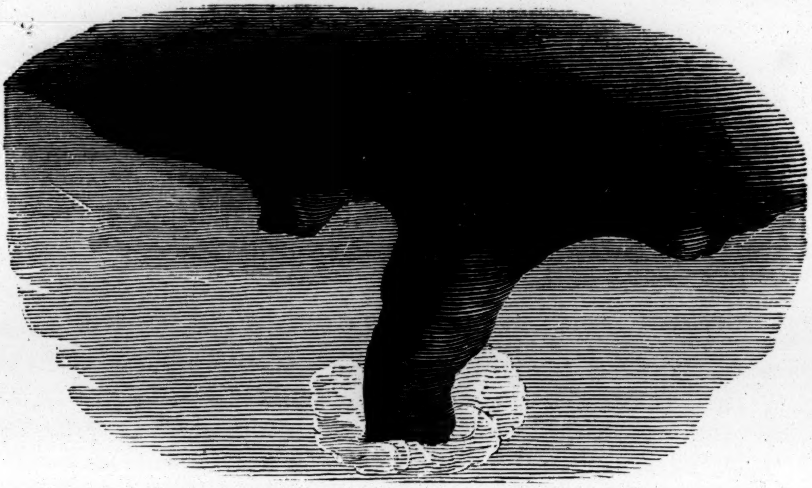
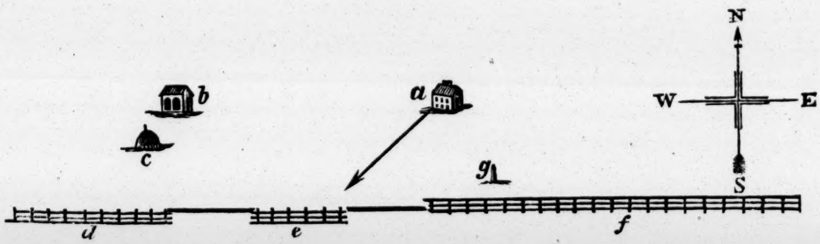


FIG. 20.



a is the house which was carried in the direction of the arrow. *b* is a stable and *c* a haystack, both untouched. These were twenty yards from the house. *d, e,* and *f* are portions of a fence which were thrown down. *d* and *e* were thrown south, leaving the intervening portions untouched. *f* was thrown north. *g* is the post already mentioned.

This was the last destruction in Keokuk county. The tornado ceased to touch the earth on Mr. Campbell's farm. It drew itself up into the cloud from which it had come down. Hitherto it had traversed a country full of deep and well wooded ravines. Here it entered upon a flat, bare country—in fact, a water-shed. It continues much the same for the seven miles which the tornado here skipped.

The storm having ceased to act as a tornado upon the surface of the earth, I proceeded to Westchester, Washington county, where it was reported to have struck. There can be no doubt, however, that a strong—though not a destructive—wind was felt over the intervening space, and that it obeyed the usual law of cyclones by blowing in spirals toward the point over which clouds continued to whirl like a great wheel.

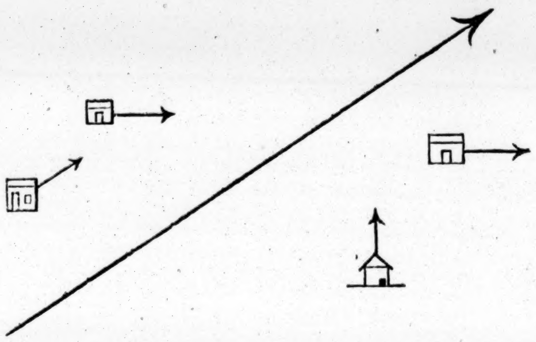
Rev. J. P. Coffman, Cedar Township, Section 33, gave the following evidence:—The tornado arrived about 3 P.M. Heard the noise for more than one hour previously. When it was hailing, heard the sound just as distinct as before. Did not hear roaring after the storm passed. The wind before the storm was nearly due south. After the storm, and with the rain, the wind came from the north and north-west. Have learned that 2 or 3 miles to the north the rain was tremendous. There was lightning in the north-west previous to the tornado. As it approached, saw light fog-like clouds, rushing, with the greatest rapidity, from the north. Its form was not so distinct before as after it passed, when it presented a decided funnel appearance. It was nearly clear in the south. When the funnel was distant about 1 mile it appeared to subtend an angle of about 25°. The funnel might have entered the dark, overhanging clouds, but it appeared to be wholly in view. There seemed at one time as if there had been a violent explosion in the revolving mass, as it was somewhat broken up. Hail larger than pigeon's eggs fell with the south wind before the storm. After the tornado the wind came from the north-west, with rain.

The tornado passed over Mr. Coffmann's house, blowing down fences about a quarter of a mile in width, and damaging buildings. It was all done by a south-west wind.

The storm-centre passed right over the house of John Maughlin, Cedar Township, Section 25. He testified that he saw a complete funnel form about 200 yards distant, and that it went up into an overhanging mass of cloud. The funnel was perfectly opaque, and left a fog behind it, so that nothing could be seen for several moments after it passed. At the distance of 200 yards it appeared to be only 15 degrees in height. Saw no lightning.

The outhouses on this farm were badly damaged. Fig. 21 shows the position of the ruins. The arrows point in the direction toward which the buildings were blown down. The fences were blown toward the storm-centre; those at the centre were carried away.

Fig. 21.



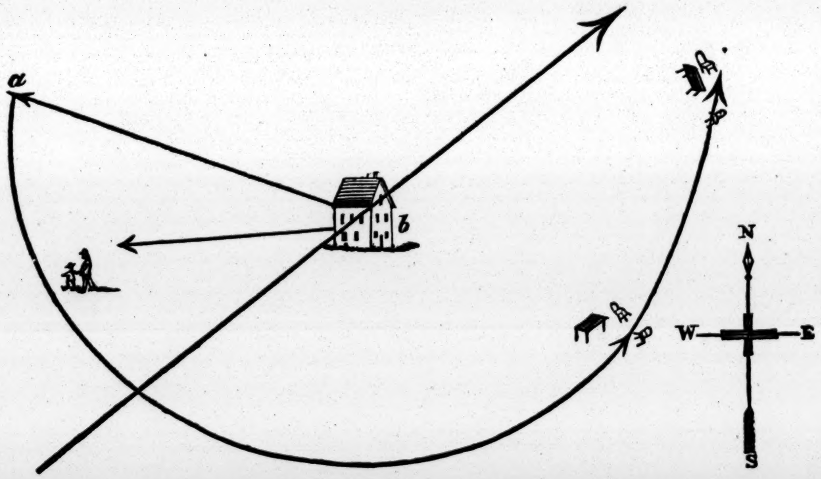
Andrew McKee, Cedar Township, Section 30, said—The clock, which had just been cleaned and regulated, was thrown down and stopped at 3.10 P.M. Previous to the tornado the lightning was warping incessantly like a snake among the dark blue clouds in the north-west. Chunks of ice, about 1 inch in diameter, fell previously to the tornado, accompanied by a light east wind.

I myself saw the clock above mentioned. It still pointed to 3.10 P.M. Mr. McKee's house stands 50 yards within the north-west limit of the storm-path. The buildings were partly pushed, partly blown down toward the S.S.E. The fences were blown to the south-east. A little empty house, about 40 yards to the east, was blown to the south-east, and some of it was carried clear across the path of the storm.

The hedges along the east and west roads are here filled full of *débris*, such as corn stumps, &c. On the south-east of the storm-centre the *débris* is driven into the hedge from the south, and on the north-west side from the north, but there is a greater extent of hedge with *débris* driven into it from the south than from the north. The position of the *débris* driven in from the north seems frequently to have been subsequently affected by a west wind. The hedges running north and south have *débris* driven into them on the north of the centre from the east and on the south of the centre from the west, but the extent of hedge with *débris* driven into it from the west is greater than that with *débris* driven into it from the east. The hedges over which the storm passed looked as if they had been whipped violently against a wall and then trailed in the mud; they were smashed and partially barked, and sometimes carried away. This description applies to the hedges over which the whirlwind, at any part of its course, passed.

George Gilchrist, Cedar Township, Section 29 (house directly in the centre of the storm-track), testified that when the storm struck the house Mrs. Gilchrist, a boy, and a child were in front of the west door, trying to reach the cave, the boy and child being a step or two in advance. The boy and child were instantly carried several rods to the west, while Mrs. Gilchrist was thrust back into the house. The house immediately went bodily, going a little to the north of the boy, who saw it go past like the railroad, as he expressed it. Its sills struck the ground 40 yards from their former position, and the house tumbled over and went to pieces, leaving the inmates comparatively unhurt. As it went to pieces it was struck by a west and south-west wind, the furniture being carried far to the east and north-east. It grew dark as midnight when the tornado struck.

FIG. 22.



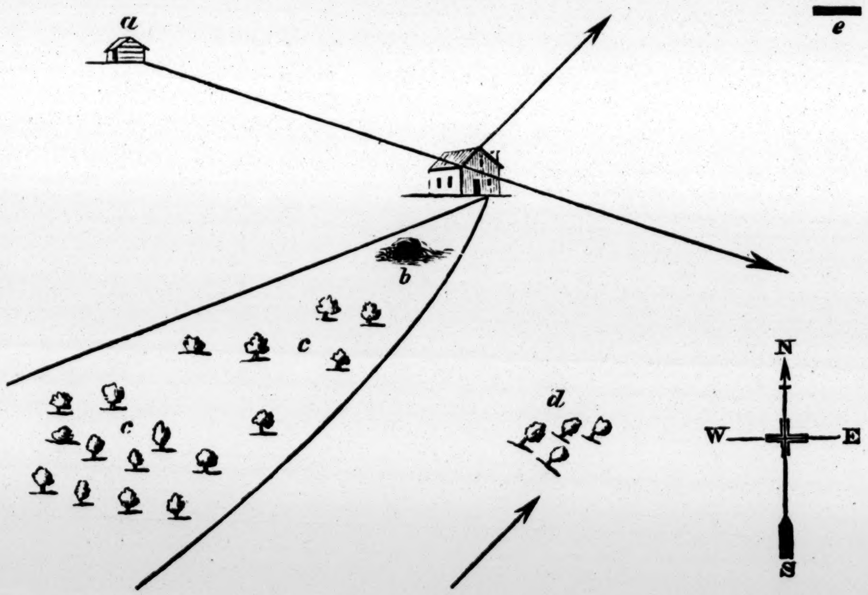
Sketch of Effects of Storm at Gilchrist's House. *a* shows the point at which the house was struck, and *b* the position at which the house stood.

When the storm struck the house of William Caldwell, Cedar Township, Section 29, the inmates were in the kitchen, which was a separate building. The wind blew so hard as to threaten to blow in the south door. Four strong men placed themselves against it: the hinges and lock were partly broken. These four men barely held the door with their utmost strength until the house went in a body: the men found themselves, together with the other inmates, a few yards to the north, lying among *débris;* the door was found a quarter of a mile away. The door presented to the wind an area of 18 square feet.

Mr. Caldwell's house stood on the south-east edge of the most violent vortex. It was first pushed 6 feet to the north-west, ploughing up the ground. The resistance of the ground and of tree roots here stopped it. It then turned up on its edge, and was then lifted over the tops of trees 20 feet high, without injuring them, and carried 100 feet to the north-east, falling entire, and going to pieces as it fell. The house stood with its end to the south; the area of this end was 280 square feet, or thereabout; the area of the floor of the house was 480 square feet, or thereabout; the weight of the house could not have been less than 20 tons. The trees over which the house was carried are young, and were probably so bent as to allow the house to rise at an angle of 45°.

A heifer, weighing 700 lbs., was carried away by the wind, and thrust head foremost into wet soil until her forequarters were buried.

FIG. 23.



Sketch of Mr. Waters's House. *a*, the Granary; *b*, the Cave; *c*, *c*, Trees uninjured; *d*, Trees hurled; *e*, Sill.

Thomas Waters, Jackson Township, Section 19, witness:—Saw the tornado coming rolling on the ground like a wave. Went to the cave, and called upon Mrs. Waters to follow; she would not. Stood in the mouth of the cave, which was 8 yards south from the house, and facing it, and saw the house blown away: it was struck from the south-west. First, a portion of the roof was blown off; then the house went bodily like lightning. When the house had gone I came out of the cave, and was blown to the E.S.E.

Mr. Waters's house was 30 × 16 × 11 feet without the roof. It was carried, sill and all, 24 yards down a declivity without being turned round or tilted over. When it struck the ground, it at first merely shaved it with the foremost sill, gradually going deeper until the resistance became so great as to cause the house to turn over, when it went to pieces. The ground was ploughed up about 2 feet at the deepest point. The house had fallen 3 feet in travelling 24 yards, Its weight was at least 10 tons.

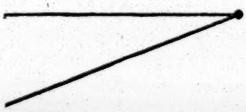
Between the cave—which was only about 4 feet above the surface—and the house, but nearer the cave, stood a small tree; against it a spade was leaning. Mr. Waters testified that it was not blown down. Two yards east of the tree stood a bucket containing a small quantity of lime, and weighing 10 lbs.: it was not disturbed. To the south-west of the cave the trees (*c*, *c*) were comparatively uninjured over a triangular space, while on either side they exhibited signs of the greatest violence. An oak sill (*e*) which had evidently been carried with the house until it struck, and then hurled due east, was driven 4 feet into the soil, at an angle of 45°. Its dimensions are 16 ft. × 8 ins., and its estimated weight 300 lbs. It was found 18 yards east of where the house struck.

Mrs. Waters was carried with the house until it went to pieces, and received injuries of which she died. The fragments of the house were carried far in the line of the storm.

Alexander Gibson had two houses, both situated as nearly as possible in the centre of the storm. The first house struck was taken away without touching the ground, and went to pieces in the air. The other house, in which were seven persons, was swung round on its north-west corner, as on a pivot, the south end travelling 36 feet, and cutting up the ground as it went. It then turned over, and was demolished. During this journey the floor was broken up, and three persons fell into the cellar. The house was a large one. It afforded no good basis for calculation, on account of the irregularity of its shape. A granary was pushed due east 14 feet: its dimensions are 16 × 8 feet; it is strongly built of generally hard wood, and divided into compartments: it was full of grain. The weight of the building and grain was given at 60,000 lbs. The resistance to its forward motion was very great, because it was surrounded with wet straw and rubbish, of which it had pushed quite a pile before it: it was racked by the strain which had been put upon it. Missiles had been driven through three hardwood planks, in succession, of an inch thick; they consisted of small pieces of wood, but had been removed. A plank 16 feet long, 2 inches thick, and 1 foot wide, was driven 4 feet into the soil, at an angle of 45°. A corn-sheller, weighing 640 lbs., was carried 400 yards, and destroyed. Trees were barked, but without any symptoms of electric action or of explosion. The general position of trees and ruins was entirely corroborative of what has been already proved by an overwhelming mass of evidence, viz., the rotation and direction of rotation of the storm.

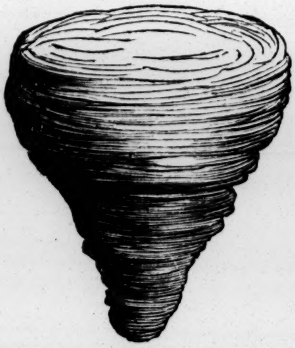
J. K. Marbourg, Jackson Township, Section 17, whose house was 80 yards from storm-centre, with an excellent view of Gibson's house, watched the storm a long time before it came. The west was first filled with clouds, which extended until they covered all the western and northern heavens, reaching a little beyond the zenith. The tornado first appeared as two clouds, one from the south-west and the other from the west rushing to one point. Together they presented somewhat the appearance of an arrow, thus :—

FIG. 24.



The whirl was seen forming when they met. Above them were dark, heavy clouds. When the tornado came nearer it presented the appearance of one funnel, revolving contrary to the hands of a watch, and drawing everything up.

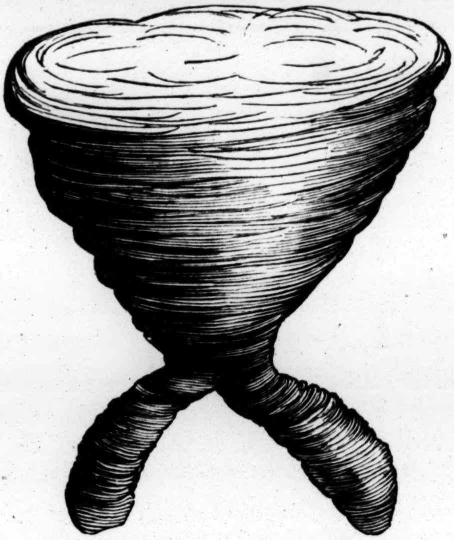
FIG. 25.



This witness related what he saw as follows :—" When at Gibson's house, where I had the best view of it, and where it was 120 rods distant, it presented the appearance of two funnels uniting in one, at the height of 40 or 50 feet. The bases of the two funnels were about 200 feet apart :

they presented somewhat the appearance represented in Fig. 26. The two funnels did not appear to revolve around each other. The first came to the east of Gibson's house, took his stable, and then turned back to his house. The two then appeared to unite. Could not see the two afterward. The tornado disappeared behind a building. It grew very dark. The funnels were of a dark blue; everything in them was rising. The timbers from Gibson's house flew up. Did not see clear sky through the open space between the two funnels, but a bright yellowish hue. The upper funnel extended to the clouds above. Hail, or rather chunks of ice, from a pigeon's to a hen's egg in size, fell before the tornado column came in sight. The wind then blew gently from the east. After the tornado had destroyed the school-house there came a violent gust of wind from the north-west, which considerably damaged my out-buildings. I had started to go to the school-house, and it carried me several yards before it. Immediately there fell a torrent of rain, with cold wind from the north. Was near where the school had been, but could not see anything. Suddenly saw the teacher and children, as if they had sprung out of the earth; they were coming toward me; they were shivering; they could give no account of what had befallen them; never saw such miserable-looking beings in my life. I had four children there, and did not recognise them. The mud was pelted into their skins, so that it could not be washed out; it is not all washed out yet. A dead child was found 40 yards north-west of the school-house. The storm oppo-

FIG. 26.



site my house was a mile wide. An oak post, 4 inches in diameter, was perforated by an oak board 4½ ft. × 4 ins. × 1 inch."

David Canier, Jackson Township, Section 20, watched the funnel as it approached. It was perfectly dark in it. Could see boards flying out at the top of it. It was very large at the top and small at the bottom. It grew dark as night. Six persons took refuge in the cellar. The house went immediately like the clap of a hand, and the darkness was already gone. Then it turned pretty dark again, and rain fell in a sheet. It did not fall in drops. It was all over in a minute. Things in the cellar were not much disturbed. Bottles stood where they were.

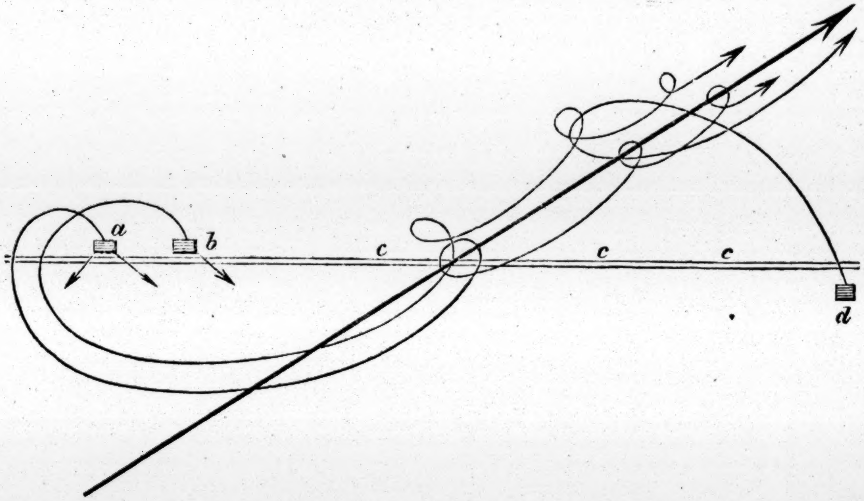
Alexander Gibson, witness: Was at Mr. Canier's house. Hail as large as pigeon's eggs fell about twenty minutes before. Heard the noise about half an hour previous to the storm. Saw clouds coming from the north and south, and rushing together. Saw the funnel when three miles distant. Watched it when 30 or 40 rods distant. It was then as black as night, with boards flying around it. A very strong wind was blowing. It grew dark as midnight. Rushed down into the cellar, and was barely down when the house was struck with a sharp instantaneous rap, and in a moment it was gone. It was dark on going down into the cellar. It was pretty clear as soon as the house went. It then grew dark again, and a tremendous rain came down. Saw no lightning. Heard no thunder. A beam was driven right through a hog.

Mr. Canier's house was 24 × 28 × 14 feet to the eaves. It was pushed 18 feet due north without touching the ground. Its edge then came in contact with the soil and with tree roots, having fallen 2 feet from its original position, and the house toppled over, and was blown to fragments. The ruins were carried first to the north-west and then around to the north-east. Heavy oak sills were carried hundreds of yards and broken. The strongest iron-bound machinery was knocked to pieces and carried away. The sickle-bar of a Buckeye machine was carried 30 rods. A beam 14 feet × 6 × 6½ inches was driven 3 feet into the soil in a slanting position. The beam weighed about 50 lbs.

A half mile to the west of Mr. Canier's house stood the school already mentioned and a house occupied by Henry Waters. Between these buildings and Canier's house, and 100 yards to the north-west of the latter, passed the storm-centre. The house occupied by Mr. Waters and the school-house were first blown to the north-west, and then in a circle by the south round to the north-east. A hedge ran along the road which connects the houses. It presented the appearances already described.

The house occupied by Mr. Waters was first blown to the north-west, the sills remaining. The sills were afterwards blown to the south-east. The sills of the school-house had likewise, after being deserted by the house, been pushed to the south-west, and, finally, the position of the *débris* among the ruins showed there had followed a violent wind from the north-west; thus a tree lay across the foundation of the school from the north-west.

FIG. 27.



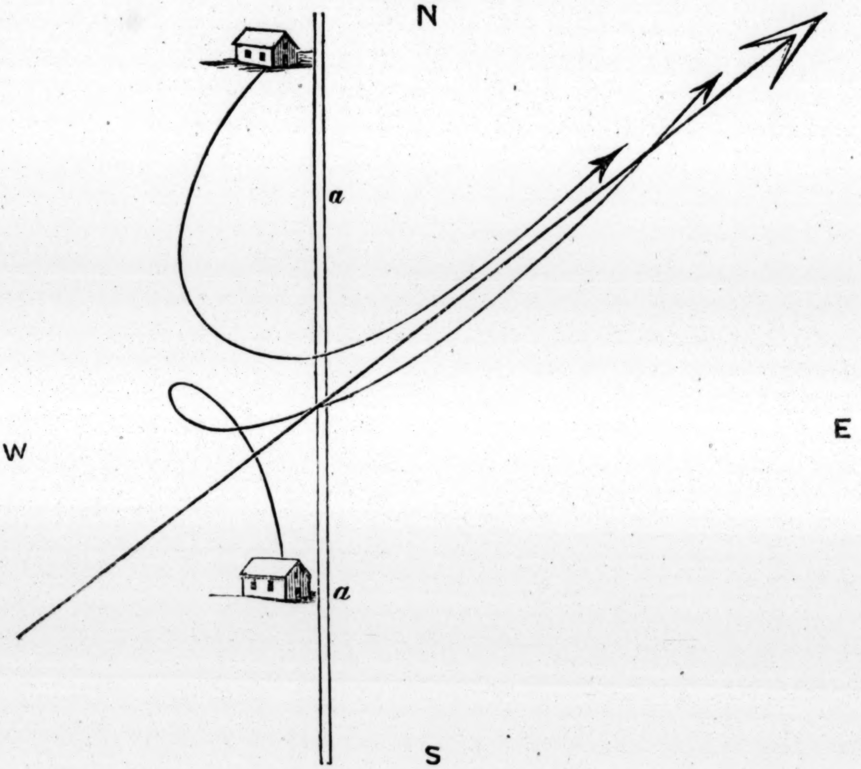
Representation of Effects of the Storm at these Houses. *a* **shows the position of the School.** *b*, **Waters's House.** *c c c*, **the Road.** *d*, **Canier's House.**

L. B. Babcock, son of J. P. Babcock, Jackson Township, Section 17, said that: Hail fell before the storm as large as pigeons' eggs. Ran to get into the cellar. Cellar door was blown over me as the house went. Came out of the cellar immediately and was blown south. The rain then came down in sheets with a north wind. The shutters from the house were carried 3 or 4 miles at least. Jacob Zek got only partly down the cellar stair and was hurt in the head.

J. P. Babcock's house was 34 × 26 × 14 feet to the eaves. The gable end faced the wind. The house was pushed bodily towards the north, crushing the northern foundation, tore up the ground a short distance, toppled over, and went to pieces. It stood on the south-east of the storm-centre.

Mr. Zek's house stands on the north-west edge of the storm. It was pushed from its foundations 12 feet to the S.S.W., ploughing up the ground. The windows on the north side were smashed in. The windows on the south and east were blown out. A haystack was entirely blown away. It went, as could easily be traced, first S.S.W., and then round in a circle to the north-east. It went 40 rods south before turning east.

FIG. 28.



Sketch of the Effects of the Storm at Babcock's and Zek's. *a a*, the Road.

The distance between these houses was about half a mile. At this point the storm-path turned a little nearer north than north-east.

F. M. Curry, Jackson Township, Section 9, tenant of John Flack's house, said: The family went to the cellar. The house went south. No one injured. Eighteen pigs blown away.

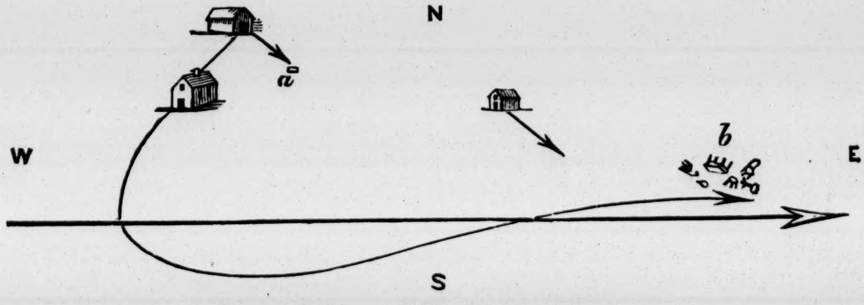
The house was pushed 45 feet due south and then went to pieces. No explosion. It was situated to the north-west of the centre.

E. N. Wright, Jackson Township, Section 10: Was on the south-east side of the storm. Saw distinctly, at the distance of 2 miles, the tornado in funnel shape. The small end was down. Saw wood whirling. Heard its roaring after it went east. There appeared to be a mist or steam in front of it. It rose and fell. Hail fell before the tornado, and an exceedingly violent rain after it.

Mr. Wright's house stands on the north-west of the centre of the storm-path, about 50 yards from it. A wood-house and a kitchen were blown south-west. The dwelling-house—a large stone structure—was moved 1 inch to the east. A stove weighing 450 lbs., and exposing to the wind a surface of 3 feet by 21 inches, was pushed 12 feet to the south-west, where it was stopped by obstructions. A bell, weighing 115 lbs., not under any circumstances exposing a greater surface than 1 square foot to the wind, and mounted 12 feet high, was broken from its fastenings, and carried 60 feet south. A granary, measuring 28 × 16 × 12 feet, and weighing, together with the grain, 55,000 lbs., was carried 21 yards to the south-east. After ploughing up the ground 2 feet in depth, it tumbled over and went to pieces. It was carried down a declivity, falling 6 feet. The width of the storm-track here was half a mile.

J. C. Cunningham, Jackson Township, Section 11: The house of Mr. Cunningham stood on the north-west of the centre of the storm-track, yet within the most violent vortex. The house was blown to the south-west; but the east door having been blown in the house went to pieces without tumbling over, and the floor remained upon the ground. The lighter furniture, &c., was carried far to the east. The granary stood to the north-east of the house. Its contents were emptied into the house cellar. The sills of the granary had remained where it was carried away. They were afterwards pushed to the south-east. The barn was blown to the south-east. A hog, weighing 200 lbs., was carried 500 yards. A cow, weighing 1000 lbs., was carried 200 yards.

FIG. 29.



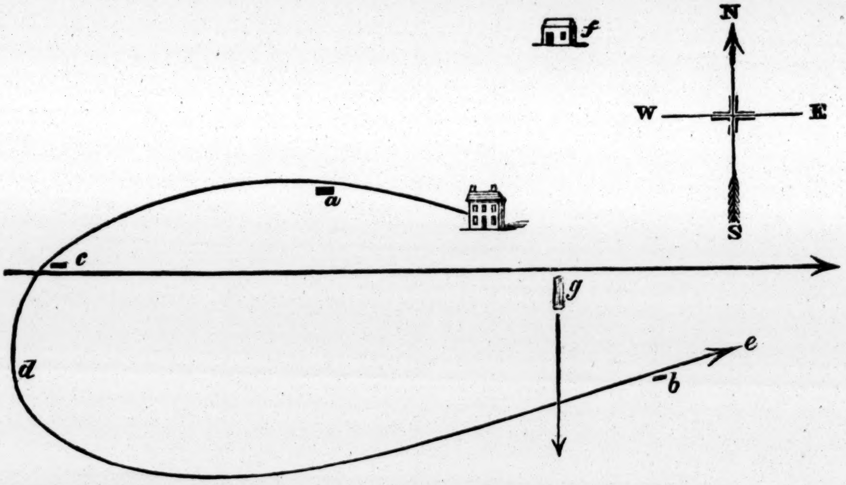
Plan of Ruins. ***a*, Sills.** ***b*, Lighter Furniture.**

There were four persons in the house and none were killed. The path of the storm is here 500 yards wide, and nearly due east.

D. T. Carringer, Jackson Township, Section 15: The house stood on the south edge of the storm. It was carried to the north-east 17 feet, going deeper into the soil as it went. It then turned over and was blown away in fragments. The straw among the trees showed that the last gust came from the north-west.

Another house struck was that of J. M. Davidson, Highland Township, Section 7. It stood precisely in the storm-centre, which here, as if conscious that this was its last victim in Iowa, seems to have exhausted its utmost violence. The house, 18 × 12 × 14 feet, was blown bodily from its foundations down a declivity towards a slough. It never touched the ground, but was shattered in the air. It seems to have been carried first nearly due west and then the lighter portions round in a curve to the east. The body of Mr. Davidson was found 20 yards west of where the house stood. The child was blown still further in the same direction. Mrs. Davidson was carried about 100 yards west. The body of Leyden Housel was found to the south-east. The heavier portions of the house were found some hundreds of yards to the west. Mr. Housel's body had evidently been carried west with the fragments of the house, and then back to the east. Mrs. Davidson and the child escaped with their lives.

Fig. 30.



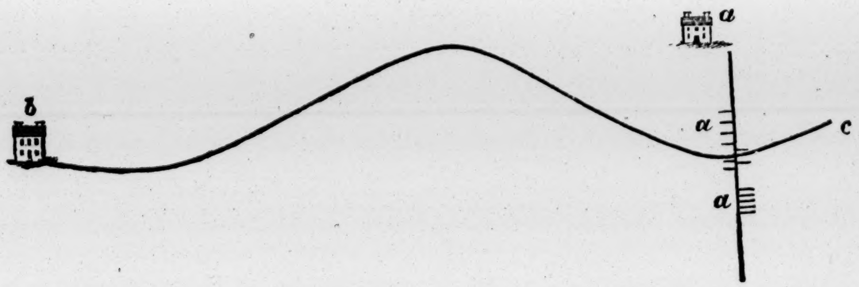
Plan of the Ruins. *a*, Davidson's Body. *b*, Housel's Body. *c*, Mrs. Davidson. *d*, Heavier portions. *e*, Lighter portions. *f*, Stable. *g*, Log.

A log of green water elm, 7 feet in circumference, 8 feet in length, and weighing at least a ton, was carried 50 yards straight south. A horse, weighing 1080 lbs., was carried 45 yards. A hog weighing 300 lbs. was blown 30 yards. The stable and barn were blown south. An iron plough, with wooden handles, was carried 150 yards. The strongest iron-bound machinery was utterly destroyed. The young trees in the orchard were either barked or torn out. The storm was exceedingly violent for a breadth of 150 yards, but fences were blown down for nearly a mile wide. At the house of Thomas Davidson, a quarter of a mile to the north, the wind blew so strongly that the door had to be held. The north wind was evidently subsequent to the east wind, because the house could not have stood such a wind.

A. Davidson, Highland Township, Section 7, witness:—It commenced to rain about ten or twenty minutes before the arrival of the tornado. Shingles and other stuff began to fall with the rain. Then went out to see where they came from. Saw the tornado about 30 rods distant; it appeared to be coming toward me. Saw it bend to the south-east; it was funnel-shaped, and as black as possible; it whirled; thought it whirled with the hands of a watch; it passed 20 rods to the south of the house, and bent again to the north-east. When 30 rods distant from the house it suddenly disappeared. Afterwards saw another funnel, not reaching to the ground, travelling toward the north-east. When first seen it appeared to be only 60 feet above the ground at its lower end. The farther it went the higher it seemed to get.

Mr. A. Davidson's house is situated $\frac{1}{2}$ a mile east of where J. M. Davidson's house stood, and a little north. The shingles and other material he saw falling came from his brother's house. The following sketch shows the direction of the storm-path after leaving Major Davidson's place until it ceased to touch the earth as a funnel; 20 rods south of A. Davidson's house it crossed a fence, exhibiting the same appearances as those already described. I was particularly careful upon this point, because of Mr. Davidson's

FIG. 30.



a, Davidson's House. *b*, Major Davidson's House. *c*, Disappearance. *d*, Fence.

belief that the funnel whirled with the sun. I thought it possible that the tornado, before lifting from off the ground, might have changed its direction of rotation. But the evidence to the contrary was so striking that Mr. Davidson at once, upon my pointing it out to him, admitted that he must have been mistaken. He had not paid particular attention to the matter, and it was very dark when his observations were being made. The fence in question ran north and south. It was only thrown down for a space of 60 yards, and the boards were not carried away except in the middle. The posts remained in the ground, those on the north of the centre leaning west and those on the south leaning east. The posts in the centre were leaning some one way, some another. The funnel disappeared upon a knoll in the midst of a hollow about ½ a mile in diameter. There was no *débris* deposited at this point, nor were there any signs of a cataract of water having poured down. The wheat, however, was mown as low as possible, and the ground looked as if it had been baked, according to Mr. Davidson's statement. The funnel had narrowed to a point before it disappeared.

After leaving Mr. Davidson's the tornado cloud travelled to the south-east. Its progress was now difficult to trace, because of the little attention usually paid to a dark cloud, a high wind, and a rain storm. Considerable time had also now elapsed since the meteor passed.

The storm passed out of Washington County into Louisa County, travelling south-east.

Joshua Luckey, Louisa County, Union Township, Section 17, witness:—The path of fences blown down on my farm was about 600 yards wide. The fences on the west of the centre were thrown north; those on the east were thrown south. Some hail fell, and a smart shower of rain. Heard no roaring after it passed.

Charles Crim, Union Township, Section 20, witness:—Fences, 200 yards wide, thrown down to the south-east. The roaring was very loud for an hour previous to its arrival. Did not hear it after it passed. Saw no lightning. Saw a tongue of cloud shaped like a funnel hanging from the clouds; it did not reach the earth; at first it was hanging perpendicular, then it commenced whirling like the tail of a suspended snake.

At this point I lost track of the tornado, and could not recover it, although I spared neither time nor pains. The inhabitants of this county appear in general to be not nearly so intelligent as those of Washington County. Only now and again could one find a man who could give any information even of what happened on their neighbour's farm a week or two before.

At this point I gave up the search, and took train for Illinois. Previous to describing its effects there the following testimony may find a place:—

H. C. Vittitoe, Warren Township, Keokuk County, about 3 miles north-west of the tornado, witness:—Saw a little south of the zenith the white under-clouds rushing in circles to a centre. The gyration was contrary to the hands of a watch. The funnel had not yet touched the earth. The wind came from the north-west pretty strong after the passage of the tornado, bringing with it a little rain and hail.

Dr. W. D. Hoffman, Sigourney, witness:—Mrs. A. T. Page collected a number of the largest hailstones. When melted, it was found that they had contained a quantity of twigs, leaves, dry grass, and mud, all reduced to fine proportions. Hailstones weighing from 4 to 8 ounces were common. One hailstone, which was shaped like an apple, measured 4½ inches in diameter. The roaring was heard about twenty minutes before the hail began; it rose and fell like the cannonading in a battle. During the hail the wind came from the north-east, but it was very light.

Sigourney is 4 miles north of the storm.

Extracts from a communication received from R. L. Jay, Harper, Keokuk County, physician:—

"Was in the village of Baden, Keokuk County, German Township, 3 miles to the north-west of the storm-path.

"The tornado maintained an upright position. It moved rapidly at times, at others seeming to remain quite still. It was apparently about a quarter of a mile in height, and was funnel-shaped, and very dark and angry-looking. It whirled with the hands of a watch. There was a continual whirling of the clouds above the funnel: this was observed for some time after the storm had passed. Saw no lightning and heard no thunder. It was impossible to hear thunder owing to the noise of the storm, which was terrific. The direction of the wind was north-east until the storm had passed, when it changed to the north-west. Rain fell in torrents. Quite an amount of hail fell, of all conceivable shapes: three hailstones were picked up weighing ½ lb. each. Half an hour after the storm the thermometer stood at 92°."

Extract from the "Sigourney News," May 28, 1873:—

"While the cyclone was mowing its path a few miles south and east of Sigourney, a tremendous hail-storm visited this locality. We saw one hailstone which weighed 8½ ounces. The hail-storm was followed by a heavy rain, after which the sun came out bright and pleasant for the rest of the day."

Extract from the "Washington County Press" of May 28, 1873:—

"The writer was in a street car, half-way from Moline to Rock Island, at 4.30 P.M., on Thursday, when it was struck dead ahead by the most terrific wind and rain storm we ever experienced."

S. J. Mather, editor "Wilton Chronicle," Iowa, witness: Between 4 P.M. and 6 P.M. a very dark cloud passed over which poured down a very heavy rain.

Extract from the "Chicago Tribune," May 25, 1873:—

"At Muscatine the rain came down as if the flood-gates of Heaven had been opened, followed by hail, Between there and Wilton Junction, at Monona, Fredonia, and other stations along the south-western division of the Chicago, Rock Island, and Pacific Railroad, the country was flooded."

The tow-boat *Victory* lost her pilot house and smoke-stack when near Buffalo, on the Mississippi. The tug *Nonesuch* lost her smoke-stack and pilot-house at Moline. She was driven ashore.

A. H. Swan, editor of the "Monmouth Review," witness: There was an exceedingly heavy rain, a little hail and a great deal of lightning about 5 P.M. The atmosphere smelt as of brimstone previously. It was oppressively hot; perhaps 95°.

The temperature and pressure on May 22, 1873, at places near the tornado:—

	DAVENPORT.		KEOKUK.		WEST UNION.	
	Bar.	Ther.	Bar.	Ther.	Bar.	Ther.
7 A.M. . . .	29·73	64°	29·64	69°	29·49	61°
2 P.M. . . .	29·60	77	29·51	85	29·46	65
9 P.M. . . .	29·69	66	29·71	72	29·53	64

The condition of the barometer and thermometer at West Union was obtained from Frank McClintock, correspondent of the Smithsonian Institute, who also furnishes the following noteworthy fact:—"Wind changed from the south to the west rapidly at 3.45 P.M. It worked back to the south before 9 P.M." The relative humidity at—

	DAVENPORT.	KEOKUK.
7 A.M.	94	85
2 P.M.	77	54
9 P.M.	94	85

We do not, therefore, overrate the relative humidity when we estimate it at 65 per cent at 2 P.M. The average temperature at the earth's surface in the line of the tornado at 2 P.M. was, from the above, probably 76°, but in the wooded hollows much greater.

Mr. Jay, however, of Harper, Keokuk County, states that the temperature was 92° half an hour after the storm. The day was generally described as being very warm.

Having arrived at Prairie City, Illinois, I endeavoured to find out the exact locality where the tornado first began to overthrow fences, damage buildings, &c. On the farm of James Williams, Point Pleasant Township, Warren County, there was a strong wind, but not sufficiently strong to prostrate fences. About 1 mile to the east is the farm of Israel Jared, Point Pleasant Township, Section 24. Mr. Jared testified as follows:—Saw streaks of cloud moving from the north and south toward each other before anything touched the earth. Saw a cloud in the form and about the size of a haystack strike the ground on my farm. A few minutes before hail of moderate size and in small quantity fell, followed, as the whirlwind was passing, by a smart shower of rain. The wind, which had been south-east, changed to the west after the tornado passed. It was pretty warm before, and cool after it. Heard roaring some five minutes previous to the arrival of the storm. Fences were blown down for 200 yards wide. They were blown toward the east. Saw some lightning. There was a heavy cloud to the north as the storm approached.

Mr. Jared's house stands about 200 yards north of the storm-path. The tornado was here travelling a little to the north of east.

John F. Tatman, Israel Jared's farm, testifies that he saw the funnel strike the farm, and that he heard the roaring for a long time previous.

Before leaving this farm the storm had developed all the characteristics of a tornado, except that the east wind was not yet powerful enough to destroy. The whirlwind then passed along a ravine full of tall timber. Nearly all the trees were uprooted or broken, but generally the latter. They appear to have had a firmer hold of the soil than those in Iowa. The breaking usually occurred about 6 feet from the ground, and the barking was almost entirely confined to the broken trees. The bark was torn off both up and down from the place where the timber was broken. The trees, when sound, were seldom broken clean across. Half or more of the wood was severed and the remainder was bent so as to allow the tree to rest upon the ground. The broken timber, when sound, invariably presented the appearance of a broom. The fibres of each year's growth were loosened from the others and split. It was easy to obtain pieces 10 feet long and as thin as a wand. This separation of the fibres had evidently been brought about by the excessive straining and bending of the tree before it fell. Each year's growth had apparently been snapped asunder by itself, beginning at the outside. The trees all lay as they had fallen, being, when once down, protected by the surrounding timber. If they had, after falling, been subjected to a wind from another direction, so as to break them off entirely, they would have presented the precise appearances which have, by certain meteorologists, been attributed to the action of electricity. Many of these broken trees were 2 feet in diameter. When a tree, still standing, had its bark torn off at any point, an examination generally showed that the fibres of the tree were separated and perhaps partly severed at that point.

The path of the tornado was exceedingly well marked among the young trees. It could be followed by the eye as far as the ground permitted. They were torn and bare, while all around was green. This barking of the young trees took place within much narrower limits than those within which grown timber was overthrown. Generally it did not extend over twenty to thirty yards in width, and was sometimes much less and even disappeared altogether. The trees exhibited the marks of the greatest violence on the side from which the storm came. The twigs were smashed and broken off, the bark partially removed, and even the timber bruised. These results were evidently the effect of a rush of missiles against the trees.

The tornado at one point suddenly narrowed the path of extreme violence from 50 yards to 12 yards, at the same time changing its course to the south-east. This change of direction brought it toward Swan Creek, along the northern bank of which it had hitherto been raging. Just as it struck the creek the track was nearly S.S.E. Immediately thereafter it turned nearly due east, following the creek. The bottom of the ravine, within which Swan Creek flows, is about 200 yards wide, is surrounded by steep and lofty bluffs, and was covered with large trees. Among these trees the whirlwind raved with the utmost fury, developing an energy surpassed at no other point in its career. Trees from 3 feet to 4 feet in diameter were snapped or uprooted. Many large trees were broken off at a height of about 40 feet and left without a twig. By far the greater number of trees along the ravine were thrown down from the south-west. The same broom-like appearance was generally presented by the broken trees as already mentioned.

Thomas Warmoth's house stood in the bottom of the ravine. Mrs. Warmoth testified as follows:—Heard a roaring first. When the storm came near the roaring was louder than thunder. Some hail fell just before the tornado blew. It was immediately preceded by a very bright flash of lightning. Went into the house and got upon my feather bed, together with my child, because I was afraid of the lightning. A large tree was blown down, catching the side of the house. The house went to pieces, the tree, however, keeping the floor in its place. Found myself under the feather bed with my child. The bed was pinned to the earth by pieces of timber. Was soaking wet. Everything was covered with mud. Heard no thunder. The lightning struck a tree, depriving it of its bark.

I was unable to find this tree. Mrs. Warmoth's testimony is valuable as a curiosity. It was generally impossible to obtain any information from the ladies. If one questioned them rigorously they took it as an insult, and if allowed to tell their own story they immediately commenced running such a muck among the prodigious and the incredible that one was glad to make his escape. In this connection it is also worth mentioning that although invariably offering payment for any necessary hospitalities, I soon learned the wisdom of always addressing myself to the master of the house when asking for such.

After leaving Warmoth's house the tornado-centre crossed to the south bank of the creek, where it continued for nearly a mile farther, although somewhat increasing its distance from the creek. It crossed to the south bank where a smaller creek joins Swan Creek from the south. This brought it nearer to the house of A. J. Caton, Swan Township, Section 15, which stands about 500 yards from the centre of the whirlwind. Part of the roof was blown to the south-east and part to the north-east. A smaller house was blown a few yards to the north-east and inverted. A house on Mr. Caton's farm, tenanted by N. J. Reynolds, 14 feet by 20 feet and one story high, was carried 8 yards to the north-east bodily. It then struck the ground, tumbled over, and was blown to fragments. Its four inmates were carried from 50 to 60 yards, but not killed. It stood a little south of the centre. After passing Mr. Caton's farm the tornado entirely left Swan Creek.

After leaving Swan Creek the storm travelled E.S.E. The first house which came in its way was that of Absolom Vandevere, Swan Township, Section 15. He testified as follows:—I have reliable information that two or three miles to the north the clouds were seen rushing south. The clouds came also from the south toward the tornado. Streaks of unusually strong wind seemed to come now and again from the south side and run into the main whirl. The wind on the north side was not nearly so strong as on the south side. Twice as much fence was blown down on the south as on the north side. Its noise resembled that of machinery, only very loud. The dimensions of my house were 36 × 42 × 18 feet.

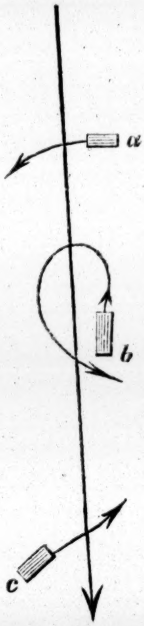
Samuel Larkins, Swan Township, Section 15:—Was at Mr. Vandevere's house when the tornado struck it. Heard roaring about 15 minutes before it came. When I first saw the funnel it did not touch the ground. Saw it whirling contrary to the hands of a watch, and the clouds were drawn in toward it on all sides. It did not lighten before the storm. It lightened a great deal immediately after it in the west. It did not hail nor rain. Did not see clouds in north or south. There appeared to be only a narrow strip of clouds. A McCormick reaper, weighing probably 1000 lbs., was carried ten rods from the south. Two horses were blown, the one 50, the other 40 yards. An axle-tree, torn from a waggon, was carried a mile and a quarter to the south-east. A shingle was driven through a half-inch ash board. It is in the possession of a Mr. Thomas. A rafter 8 feet × (2 × 4) inches, was driven through three hogs and thrust into the ground a foot and a half. All three were on it when it was found. A picture-frame was picked up with the glass unbroken. The wind blew very strongly for about two minutes.

Mr. Vandevere's house, 36 × 42 × 18 feet to the eaves, stood north and south lengthwise. It was moved due north half the length of the house, tumbled over and blown to pieces. It stood with its north end exactly in the centre of the vortex. There were nine persons in the cellar and two in the house. One of those in the cellar was killed by a log. The trees around the house and within the narrow path of the greatest violence, all pointed to the E.S.E., the direction in which the storm was travelling.

W. J. Jones, Swan Township, witness: Vandevere's house is forty rods to the north. Myself and wife were in my house when it was blown away. It grew dark as midnight just then. There was a little hail before. Did not notice any rain. The house did not go very fast.

Mr. Jones's house was 22 × 16 × 12 feet to the eaves. It was pushed entire 5 feet to the north-east. It then toppled over and was blown to pieces.

FIG. 31.



Sketch of Storm Effects at Larkin's, Vandevere's, and Jones's Houses.
a Larkin's House; *b* Vandevere's; *c* Jones's.

The fragments in Illinois had already been gathered from the fields, rendering it more difficult to trace the ruins in their flight.

William Thomas, Swan Township, witness:—The centre of the storm passed a quarter of a mile to the north. An unoccupied house stood in its way. It was lifted from its foundations and then broken to pieces. Horses were carried a good way and killed. A rail was driven through one of the cattle, going in beneath her tail and coming out at her shoulder. Saw only one funnel.

Such is a statement of some of the facts connected with the Iowa and Illinois tornado of May 22, 1873. I spared no pains in order to render it scientifically complete, sometimes travelling miles under a fierce sun, and with a temperature among the nineties, in order to obtain the evidence of one man. The information given by any witness by no means represents the number of questions asked him. These were extensive and calculated to extract all the knowledge on the subject possessed by those under examination. For instance, the following question was addressed to all and sundry: Did you observe any pointed objects, such as lightning-rods, posts, &c., tipped with flame, during the progress of the tornado? but the replies being uniformly in the negative, have not been formally inserted in the statement of facts. Also a description of the sound was exacted from all witnesses, but only a few typical ones have been inserted. I regret this at present, because I have learned from experience that very important questions may attach themselves to a description of the sound. While interrogating parties the utmost vigilance was exercised to prevent them from giving conclusions for what they saw and heard. This was a very troublesome point and caused the interrogator to appear in many cases in the highest degree rude; while it also excludes from these pages the names of persons who observed accurately, but who are unable to distinguish between the *esse* and the *ergo*.

The statement of facts for Iowa is much more exhaustive and instructive than that for Illinois. There are several reasons for this.

1. Some weeks had already elapsed since the tornado, and its traces were becoming rapidly obliterated, both in the memories of the witnesses and upon the surface of the earth.

2. It was later in the day when it occurred, thus hiding the light of the sun more completely by the tornado clouds as they approached, and rendering it more difficult to observe accurately their forms and proportions.

3. The storm in Illinois seems to have been of a somewhat different character from that in Iowa, by its form rendering observation more difficult.

With regard to the angles of elevation given, it must be borne in mind that they are only approximations. Very few indeed of the witnesses have accurate conceptions of angles. I generally made them point in the direction in which an object was seen, and so estimated the angle.

CALCULATIONS AND CONCLUSIONS.

The Idea of a Tornado in General.—The tornado consists essentially of a rapidly ascending current of air. This involves two other functions—(1) a rushing in of the air at the under part of the ascending current or column; (2) an out-rushing at the upper. Upon the former of these functions, combined with modifying circumstances, depends the peculiar character and career of the under currents and of the clouds they bear; upon the latter, combined with the same circumstances, the proportions and direction of motion of the upper currents of the heavy masses of clouds they bear. There appears to be nothing in the nature of the tornado itself which can determine the motion of either the upper or under current more towards any one point of the compass than toward the others. This direction of motion relative to the ascending column depends upon the direction and velocity of motion of the latter and of the atmospheric strata in which the influx and efflux take place, modified to some extent by the differing velocities of revolution of the surface of the earth at different parallels of latitude, by the form of the earth's surface, and by the variation in the constitution of the atmosphere. If the tornado column, and the atmospheric strata which it penetrates, move in the same direction and with the same velocity, the influx and efflux will take place in nearly equal quantity on all sides of the column. If they move with different velocities the directions of exaggeration and diminution of the influx and efflux can be calculated in the same way as the direction of a wind-vane on a ship's mast, given the directions and velocities of the motion of the wind and of the ship.

General Idea of the Tornado of May 22, 1873, in Iowa.—A huge, dark cloud covered an area at least 30 miles in diameter. Under the south-west edge of this cloud there moved a perfectly opaque funnel-shaped appearance, reaching from the ground to the clouds. Towards its base the wind, in spirals, rushed violently from all sides, overthrowing, when in immediate proximity to or within the opaque vortex, whatever opposed its progress. Towards its summit, where it disappeared in overhanging horizontal cloud, long streaks of clouds rushed in spirals from all directions. Viewed from a distance they appeared to come from opposite directions, and move swiftly towards each other at right angle to the observer's line of vision. Between the surface current and these centripetal clouds the air doubtless obeyed the same forces, and rushed in spirals with ever-increasing velocity towards the opaque funnel.

Under the remainder of the lofty cloud which defined the limits within which the outspreading of the ascending air was taking place, and which lay chiefly to the N.E. of the rising column, there raged a tremendous storm of hail and rain, accompanied by incessant and brilliant electrical phenomena.

More Particular Description, Dimensions of the Meteor, and of the Centrifugal or Upper Current.—The data for determining the horizontal extent of the cloud are not very precise. There is a general concurrence of the witnesses that it reached only a few miles to the south of the tornado, and that very little rain or hail fell there.

There is also a general agreement among the witnesses that a little hail fell some minutes before the advent of the funnel, and a little rain immediately after its passage. The whole appears to have occupied at least thirty minutes in passing. This would give the cloud at the funnel a width of at least 15 miles in the line of its progress. Probably it was considerably greater. We may, therefore, safely conclude that we are within the limits where we assign to the centrifugal cloud an average horizontal diameter of 30 miles.

I have no data for determining the elevation of the under side of the centrifugal cloud beyond what is involved in those for measuring the altitude of the centripetal. There must, however, have intervened a very considerable space between the two. For if there was nothing intervening there could be nothing to prevent the under, and specifically lighter, air from taking the shortest way up. There could be no reason why it should first rush to a centre, ascend there, and then rush from it.

Dimensions of the Centripetal Current.—The data for determining these are still less precise than the preceding, but yet sufficiently so as to give a more definite idea than any mere description in general terms.

The witnesses generally testify that hail fell from fifteen to thirty minutes before the whirlwind, and rain for as long a period after. They further almost unanimously say that the wind was easterly with the hail and westerly with the rain. If we assume twenty minutes as the duration of each of these winds, we obtain 20 miles as the diameter of the inrushing winds at the earth's surface.

If the disturbing influences were not much greater at the earth's surface than at a higher altitude, the dimensions of the whirl should, within the limits of the centripetal wind, owing to the absence of friction, vastly increase as we ascend. Moreover, since the funnel was first formed at a considerable elevation, and since it touched the ground with a narrow point, and merely incidentally, as it were, since it for long distances ceased to strike the earth, and yet proceeded with undiminished energy; since, in short, both the originating and sustaining sources of its power seem to have mainly existed high in the atmosphere, we have the strongest reasons for concluding that the horizontal dimensions of the centripetal current was very much greater at its more elevated portions than at its base. It would therefore appear to be not unlikely that the diameter of the centripetal current was not greatly exceeded by that of the centrifugal.

The Dimensions of the Funnel.—The data for calculating the dimensions of the visible portion of the funnel are more numerous than precisely accurate; but I conclude that the tornado column was, from a favourable position, visible at some parts of its course to a height of between 1 and 2 miles.

Wherever there was evidence of the funnel having touched the ground there was, to a greater or less breadth, what I have designated as the vortex of extreme violence, varying from 100 yards in breadth to nothing. Without having positive evidence, and notwithstanding that there was everywhere a gradual diminution of violence from the centre to the circumference except in the remarkable phenomenon of streaks or arms, and no abrupt transitions, I could not help concluding that the path of greatest violence was identical, or nearly so, with the diameter of the base of the funnel when it touched the ground. This would give it an average diameter of about 30 yards. The witnesses are generally agreed that the summit was several times wider than the base. If we assume that the visible top was five times the diameter of the base, we have, say, for the altitude of 1 mile, a diameter of only 150 yards. I think, however, that, owing to its great elevation and the optical delusion connected therewith, and the general belief of the spectators, that the funnel was, at the very utmost, only a few hundred feet high; the diameter of the summit was very much greater.

The Changes seen in the Funnel.—Some observers saw only one funnel, others saw two funnels superimposed with the narrow ends together, and the smaller one beneath, while a great many saw two and even three funnels side by side. The evidence on all these points is beyond question. At first I was inclined to believe that two or more funnels had actually touched the ground and travelled side by side. The sketch of the storm by R. F. Campbell seemed to favour this explanation. It shows a protuberance on each side of the funnel, which looks like an inceptive funnel. The fact that a second funnel should travel along the south-east side of the main one without disturbing the symmetry of the action of the latter, as exhibited by the ruins, did not appear altogether incredible, for it is abundantly evident from the statement of facts that the damage was done by a wind blowing in the path of the tornado when the black funnel hovered above or slightly touched the ground. Thus an incipient funnel, moving along the south-east side of the main funnel, and occasionally making a dip, would produce no appreciable discord in the disposition of the ruins. An insuperable objection to this theory was found in the unanimous testimony of the eye-witnesses that the funnels approached each other and combined to form one. Another objection was found in the lack of unity thus introduced into the conception of the magnificent whole. Finding this explanation untenable, I endeavoured to think the possibility of smaller auxiliary funnels, each of them a perfect whirl, moving in spirals nearly or altogether identical with those pursued by the confluent winds. This I found to be more difficult than the first. The chief objection was the total lack of a conceivable cause of the existence of these smaller whirls. The second was the peculiar circumstance that while one observer saw two funnels, another in the same position saw only one, or saw two superimposed with the smaller ends together. No possible arrangement of two independent funnels with the smaller ends down could produce the optical illusion of the funnels superimposed with the smaller ends together. I found what I believe to be the key to the difficulty given by Mr. Marbourg while considering the delineation of the two funnels joining in one funnel. The other observers who saw two or more funnels evidently had the whole of their attention confined to these, and did not observe what was above them. He saw the two combine at what he estimated an altitude of 50 feet, and form one. Another witness at the same place and time saw only one funnel. At Lancaster some saw only one, others saw two superimposed, and others saw two side by side and all at the same time. There is, therefore, an unavoidable necessity for some explanation to reconcile these antagonistic appearances.

There is excellent evidence to show that the funnel moved at its base with a sort of pendulum motion; that it seemed to stand still for a moment and then to bound suddenly forward. The evidence on this point is so general that we need not recapitulate it. But we have no reason for supposing that this oscillating motion extended to any considerable distance above the ground, for it is only in the want of homogeneity of the atmosphere and the resistance opposed to the free course of the winds by the earth's surface that we can find a cause for this pendulum motion. Let us suppose that the funnel is over, a well-watered and well-wooded ravine, with its path at right angles to it. It is evident that the air at some distance above the ground will offer much less resistance to the forces drawing it into new paths than that on the surface when the friction is so important an element. In the forward march of the tornado the base would thus be somewhat left behind. The warm, moist air of the ravine would increase this tendency on account of its specific levity.

But the inrushing winds follow the path of least resistance toward the area of greatest rarefaction. The bending, therefore, cannot proceed far before the south-west winds, whose direction of motion is carrying them away from the base of the inclined funnel, will find less resistance and a shorter path towards the greatest rarefaction by striking up into the nearest point in the side of the funnel.

A streak of rarefaction great enough to produce condensation is thus generated. This arm of the funnel affording the shortest way for the winds will increase with rapidity. The other will decrease, becoming mainly confined to the north-west winds. Meanwhile the intervening air will become rarefied and set in motion; the two arms will suddenly unite, and the funnel present again its original proportions. These transformations must take place within a brief space of time, for the tornado is travelling at the rate of half a mile per minute. When we consider, in addition, the darkness, we shall be at no loss to conceive why these two branches should present the appearance of one funnel with its larger end down, and why to a less favourably situated or more superficial observer the whole should appear as one.

One difficulty yet remains to be obviated. Since the arm moves forward in a spiral to the centre, and the velocity of the inrushing winds at the funnel far exceeds 100 miles per hour, how is it possible for the observer in the darkness to notice the appearances distinctly? Mr. Marbourg gives the distance between the two arms at 200 feet. This space would be traversed in one second by winds of so great velocity, and the condensed vapour would fill the whole space before it had time to disappear. The very velocity itself would render distinct vision difficult. We must not, in short, confound the path of the winds with the winds themselves. While the winds were rushing up in a slanting and curving direction along these arms, the arms themselves might be moving forward with a much less rapid motion. If it were possible to determine the inclination of these arms to the perpendicular it would aid in calculating the force of the wind. Mr. Marbourg stated that the distance between the bases of the two arms was 200 feet, and the height, when they joined together, 50 feet. He gave 80 to

100 feet, however, as the height, to the editor of the "Washington County Press." His own delineation formed the belief that the height was greater than 50 feet. He could easily judge of the distance between the arms, but was very liable to be mistaken in estimating the height. The error, therefore, will probably not be great if we assume that the funnels joined together at the height of 100 feet. This would give these arms an inclination of 45°.

The Direction in and the Velocity with which the Tornado Travelled.—From its starting-point on South Skunk river until it reached North Skunk river, a distance of 10 miles, the tornado travelled in an E.N.E. direction. It there turned a little south of east and followed the course of that river for 2 miles. It then went E.N.E. until it came to Rock Creek, when it turned a little west of north and followed the course of the creek for a short distance. It then travelled north-east until it ceased to touch the ground 3 miles from Keota. After lifting itself from the ground it travelled about E.N.E., striking again at Westchester, Washington County. From this point until it reached Enoch Wright's, a distance of over 9 miles, its course was nearly straight, varying between N.E. and E.N.E. Its course then became very crooked, bending in curves from north-east to south-east, and *vice versâ;* but on the whole travelling east, until it came within a mile of the confines of Washington County, when it made a decided turn to the south-east. Here its path lay down the declivity towards the well-wooded ravine of Goose Creek. When within half a mile of the creek its traces became so feeble that it was impossible to track it further. It was at this point, within 1½ miles of Iowa river, that the crookedness of its path reached its maximum within the last half mile of its career, before ceasing to touch the ground, as a black funnel at A. Davidson's farm, Highland Township. Within this half mile it bent just a little to the south-east, then to the north-east, then to the south-east, and again back to the north-east, when it disappeared.

After leaving Crooked Creek, at the commencement of its career in Washington County, and until it reached to near Goose Creek, the tornado traversed an elevated, well-cultivated region, almost totally devoid of trees and water-courses. There was apparently nothing in the configuration of the ground over which it passed which could account for its changes of direction. These changes, moreover, were not generally abrupt, the tornado sweeping in graceful curves from one direction to another. It is to be noted, however, that the curving of its path commenced after it came within the influence of the moister warmer air of the Iowa river, and that the general deviation of its course from the north-east direction, which it had on the whole hitherto followed, led it down the valley of the Iowa river.

In order to determine the velocity with which the meteor travelled, it was necessary to obtain the precise time of its arrival at different points. The difficulty of obtaining precise time in an agricultural district is always considerable. In addition, no one thought of looking at his clock or watch. Hence, although every witness was questioned on this point, there were but few who could even approximate to the time. The majority thought that they had a remarkably definite idea when they could tell between what hours it occurred. Reliable time it is believed was obtained at least at two places in Iowa—at Wolfden school-house, Lancaster Township, Keokuk County, and at A. McKee's house, Section 23, Cedar Township, Washington County. The times obtained at these places were corroborated by the testimony of those likely to be best informed. The tornado struck the school at 2.15 P.M. It arrived in Section 23, Cedar Township, at 3.10 P.M. The distance between these places in a straight line is 27 miles. This gives a velocity of 29·4 miles per hour. The crookedness of its course, though not great, would bring its velocity along its path to 30 miles per hour at least.

The Direction of the Centripetal Winds.—The wind blew in spirals toward the centre of the vortex, the direction of revolution being contrary to the hands of a watch throughout the whole course of the storm. The evidence in support of this, as given in the statement of facts, is overwhelming, and recapitulation unnecessary. The mere fact that all who had an opportunity of seeing the funnel saw that it was circular is sufficient to prove that it was a whirlwind, for on no other hypothesis could the circular form be accounted for. Then the witnesses, almost without exception, saw this funnel whirling contrary to the hands of a watch. Then the illustrations of the position of the ruins of the houses, and of the fallen trees, &c., prove beyond a doubt that a merely centripetal wind could not have done these things. Again: that the wind was not blowing in circles round the centre is sufficiently demonstrated by the fact that everything, except within the most violent vortex, was thrown toward the centre; the ruins invariably lay most thickly there. The only form of motion capable of producing these effects is a mean between the circular and the direct centripetal,—to wit, the spiral. The illustrations give copious ocular demonstration that such was the case. The ruins of houses, whenever they could be distinctly traced, proceeded in the curve towards the centre, which apparently was always reached before the completion of an entire revolution. This does not imply that the centripetal winds never performed a complete revolution before reaching the centre, but only that from within about 100 yards of the centre this did not take place. Ruins carried from that distance seemed generally to reach the centre in about two-thirds of a revolution. This led me to assume at about 100 yards from the centre the wind generally made an angle of about 25° with the tangent. This gives a centripetal component compared with the circular as 0·42262 is to 0·90631.

Besides its horizontal motion, the wind had necessarily an ascending motion, which reached its maximum at the centre and its minimum at the circumference. The necessity for this lies in the proof of the centripetal motion of the wind. Otherwise the centripetal motion of the wind would require to double itself at half the radius from any point toward the centre: this would soon give it a motion infinitely great, which is absurd; there would also be no means of escape for it at the centre. To a great many excellent witnesses the funnel presented the appearance of a screw with its thread running upwards. In addition, all objects within the sphere of the tornado seem to have been partly lifted, partly pushed forward. We have seen that at A. Gibson's house the arms made an angle with the perpendicular of probably about 45°. Since these arms, as there is every reason to believe, were inclined in the normal direction of the winds, which is that of least resistance, we are justified in assuming that in the black funnel itself the inclination of the winds to the horizon was at least as great, and probably greater.

The Velocity of the Wind.—This is a very difficult topic; the task would have been much easier if we had been dealing with a horizontal wind merely. If even the perpendicular and horizontal components were invariable, the hope of a tolerably accurate solution of the problem would be much greater; but while the former decreases from the centre to the circumference, the latter increases. In order that no chance of a solution might be lost, I give the following from data I collected:—

1. A school-house, weighing 30,000 lbs., was pushed 25 feet from its foundations. The surface exposed to the wind = 360 square feet + the roof, which had a slant of 45°.

2. A house, exposing 280 square feet to the wind, having a floor of 480 square feet, and weighing 20 tons, was pushed 6 feet from its foundations. It was then lifted over the tops of trees 20 feet high.
3. A house, presenting to the wind a surface of 176 square feet without the roof, and weighing 10 tons, was carried 24 yards while falling 3 feet. The wind struck it nearly on the end.
4. A granary, exposing 128 square feet of surface, and weighing 60,000 lbs., was pushed 14 feet.
5. A house, exposing a surface of 392 square feet, + the slanting roof, and weighing 20 tons, was carried forward 18 feet while falling 2 feet.
6. A house, exposing 533 square feet, and weighing about 25 tons, was pushed from its foundations.
7. A granary, exposing a surface of 256 square feet to the wind, and weighing 55,000 lbs., was carried 21 yards while falling 6 feet.

If we estimate the static friction of a frame house upon a stone foundation, or upon posts firmly fixed into the ground, and to which it is nailed, at one-half the weight of the house, it does not seem likely that we shall err by excess. Upon this basis it is easy to calculate the minimum velocity of a horizontal wind necessary to push it from its foundations. The difficulty is that we are dealing with a wind having a perpendicular component to its velocity. If the wall of the house was perfectly smooth, and since the air is nearly perfectly elastic, the only force exerted upon it by a wind blowing at any angle to its surface would be perpendicular to that surface. Moreover, whatever force the perpendicular component may exercise upon the wall, owing to its roughness, must have upon the house the effect of an overturning rather than a lifting power. But, since friction is independent of extent of surface, this overturning power would not assist in overcoming friction. The fact, also, that the houses, while being carried bodily through the air, were not made to spin round on an axis by this perpendicular component,—there being then no resistance, beyond inertion, to motion in a circle,—would seem to prove that its effect was not great. It would therefore appear that an approximation may be made to the velocity of the horizontal wind, by simply calculating—upon the given assumption of the relation of weight to friction—the minimum force required to push these houses from their foundations. The following are the results for the given cases :—

1. Pressure per square foot 41·7 lbs. Velocity of wind, 91·3 miles per hour.
2. Pressure, 71·4 lbs. Velocity, 119·5 miles.
3. Pressure, 56·8 lbs. Velocity, 106·6 miles.
4. Pressure, 234·3 lbs. Velocity, 216·5 miles.
5. Pressure, 51 lbs. Velocity, 100·9 miles.
6. Pressure, 46·9 lbs. Velocity, 96·8 miles.
7. Pressure, 107·4 lbs. Velocity, 146·6 miles.

Only one of these buildings was not, in addition to being pushed from its foundation, carried away, viz., case 4. It, however, was pushed through a dense mass of tough rubbish, and its sides were bent from the perpendicular. Owing to its small surface and great weight, the force of the wind exceeded the minimum required to push the building from its foundations less in this case than in any of the others. Hence we have the great velocity of 216·4 miles per hour, or of 317·4 feet per second, in a horizontal direction. It is also probable that in this case the kinetic friction was greater than the static, and that it increased every moment until the building came to a stand.

The Amount of the Precipitation.—It was impossible to obtain more than generalities on this head. There were no rain-gauge measurements, so far as I could learn. At Davenport, however, a few miles from where damage was done on the Mississippi, there fell, on May 22, 1·35 inches, as shown by the Signal Service Reports. From the description of the rain to the north of the funnel, in Washington County, a greater quantity than this must have fallen at many places. It is not, therefore, likely that we shall overestimate the amount when we assume that 2 inches of rain fell over an area 10 miles in width. Since the tornado travelled 30 miles per hour, this gives a rainfall per minute of—

$$\frac{2 \times (10 \times \frac{1}{2}) \times 3{,}097{,}600 \times 9 \times 144}{1728} = 23{,}232{,}000 \text{ cubic feet.}$$

Tornado Dynamics.—A cubic foot of water weighs 1000 ounces. The weight of water which fell per minute was therefore—

$$\frac{23{,}232{,}000 \times 1000}{16} = 1{,}452{,}000{,}000 \text{ lbs.}$$

It is not, probably, an exaggeration to assume that this mass of water fell, on an average, 6 miles or more. This gives a horse-power of—

$$\frac{14{,}522{,}000{,}000 \times (6 \times 5280)}{33{,}000} = 1{,}393{,}920{,}000,$$

generated by the falling water.

From the calculations of the velocity of the wind it is not probable that, when we assume—at the distance of 100 yards from the centre—an average velocity of 120 miles per hour, we overrate it. The angle which the wind made with the tangent was probably about 25°. The wind, therefore, on these bases enters a cylinder of 100 yards radius at the rate of 50 miles per hour, or 4400 feet per minute.

From the calculations of the height of the centripetal current we have seen that it probably extended over 2 miles. Let us assume that its height was 2 miles. Let us assume, also, that the velocity with which the wind entered the cylinder was equally great throughout its length. We have then the following data for calculating the quantity of air which enters this cylinder of 100 yards radius, or 628,318 yards circumference per minute. It amounts to $(628{,}318 \times 3) \times 4400 \times (2 \times 1760 \times 3)$ c. ft. $= 87{,}582{,}502{,}656{,}000$ cubic feet. Since this volume is calculated from the mechanical effects or force of the wind, and since the relation between the force and the velocity of the wind is calculated for the average pressure, it matters not, in calculating the mass of the above volume of air, what the barometric pressure was at the distance of 100 yards from the centre. The difference of pressure due to elevation must, however, be calculated. Since the average pressure at sea-level is about 30 inches, at an elevation of 1 mile about 24·60 inches, and at an elevation of 2 miles about 20·20 inches, and taking into account the correction due to the elevation of the country over which the tornado passed, 24 inches would be about the mean pressure up to 2 miles of elevation. The density of the air varies with the temperature. The temperature around the tornado must have been, at a fair exposure, about 76°, but was in deep wooded ravines no doubt much greater: since the temperature diminishes 1° for every 300 or 400 feet of elevation, we may assume the average temperature to have been, within the limits of the centripetal current, about 60°. The relative humidity was about 65 per cent.

The weight of a cubic foot of air, at a pressure of 24 inches, a temperature of 60°, and a relative humidity of 65 per cent, is 426 grs., or thereabout. The total weight of air, therefore, entering the column per minute amounts to—

$$\frac{87{,}582{,}502{,}656{,}000 \times 426}{7000} = 5{,}330{,}020{,}875{,}922 \text{ lbs.}$$

This weight of air moves, by hypothesis, at the rate of 120 miles per hour, or of 176 feet per second. This velocity is acquired from the acceleration due to gravity in falling through a space of 481 feet. The power, therefore, generated by this mass of air moving with the given velocity amounts to—

$$\frac{5{,}330{,}020{,}875{,}922 \times 481}{33{,}000} = 77{,}689{,}092{,}161{,}166 \text{ horse-power.}$$

The latent heat of evaporation amounts to about 1000°. Consequently the condensation of 1,452,000,000 lbs. of vapour is accompanied by the evolution of 1,452,000,000 × 1000 calorics or pound degrees of heat. The specific thermal capacity of air, as compared with water, is as 0·237 to 1. The number of degrees, therefore, which this amount of heat would raise 1 lb. of air is—

$$1{,}452{,}000{,}000{,}000 \times \frac{1000}{237} = 6{,}126{,}582{,}278{,}481 \text{ degrees.}$$

But the pressure remaining the same air expands $\frac{1}{491}$ part of its volume for every accretion of 1 degree of temperature. This amount of heat would therefore expand 1 lb. of air

$$\frac{6{,}126{,}582{,}278{,}481}{491} = 12{,}477{,}764{,}315 \text{ times.}$$

A cubic foot of air at 30 inches pressure, 60° temperature, and having a relative humidity of 65 per cent, weighs 538·6 grains. A pound of such air, therefore, occupies—

$$\frac{7000}{538{\cdot}6} = 12{\cdot}99 = 13 \text{ cubic feet very nearly.}$$

A pound of air, therefore, in doubling its volume must—the pressure remaining 15 lbs. per square inch—raise a weight 13 × 144 × 15 = 28,080 lbs. through 1 foot. The total amount of work, therefore, performed by 1 lb. of air, while expanding—under a pressure of 15 lbs. per square inch—to 12,477,764,315 times its original bulk, is 12,477,764,315 × 28,080 foot-pounds. This amount of work accomplished per minute demands—

$$\frac{12{,}477{,}764{,}315 \times 28{,}080}{33{,}000} = 10{,}617{,}443{,}089{\cdot}8 \text{ horse-power.}$$

We thus see that the power generated by the condensation of the amount of vapour estimated as having been precipitated is much less than that calculated to have been produced by the velocity of the centripetal winds. Theoretically, this power should be diminished by the amount of expansion counteracted by the removal of so large a mass of vapour. Practically, however, it seems probable that this removal of vapour, while increasing the specific gravity of the air, serves rather to increase the rarefaction when taking place with great rapidity.

The horse-power required to raise 5,330,020,875,922 lbs. to a height of 5 miles per minute amounts to—

$$\frac{5{,}330{,}020{,}875{,}922 \times 5 \times 1760 \times 3}{33{,}000} = 4{,}264{,}016{,}700{,}737{\cdot}6 \text{ horse-power.}$$

These figures convey a better idea of the tremendous power of the tornado than any mere verbal description could do. They also show that the power evolved by the condensation of vapour, while enormous, is by no means sufficient to supply the whole energy developed by the tornado. We must therefore look for another source of power. This is no doubt to be found in the destruction of the atmospheric equilibrium by an abnormally warm southerly current flowing under a much colder, and consequently specifically heavier, stratum of air.

In an extensive paper, which will be found in the Chief Signal Officer's Annual Report for 1873, the author passes on to the consideration of the general atmospheric conditions under which the tornado originated. The length of this article, however, precludes our entering fully into this branch of the subject.

The Electrical Phenomena must be regarded as merely secondary. In the lofty centrifugal cloud there was incessant thunder and lightning; but very little, if any at all, in the centripetal cloud and the funnel. One object, a tree, was struck in the path of the storm, but the discharge took place half an hour before the arrival of the funnel. The lightning-rod said to have been melted on widow Dogget's barn might have been struck long before, and only noticed then because it was blown down.

There were no evidences of electrical action upon the trees, which were peeled and shivered by the storm, although there was that brown appearance when the trees were broken which has been referred to the action of electricity. This, however, was clearly due to the straining of the tree before it broke.

No one saw any objects tipped with electrical light during the progress of the meteor. The telegraph was not interrupted until the wind blew down the wires.

It is the generally-accepted opinion that in tornadoes houses are frequently burst asunder when the centre of the whirlwind comes over them. This is supposed to be accomplished by the great rarefaction, which is said to exist in the centre, suddenly relieving the air within the houses of a large portion of atmospheric pressure. The air thus relieved of pressure immediately expands and blows the house asunder, as with gunpowder. There was not, so far as I was able to learn, a single case in which a house was so destroyed. The houses were invariably demolished or blown from their foundations by a wind blowing in a certain direction. They were generally pushed or carried a considerable distance bodily, floor and all. After striking the ground with the foremost edge they turned partially over, thus exposing the floor to the wind. The wind, being obstructed by the wall of the house resting on the ground, became immediately compressed by the pressure from behind. The floor, unable to stand this pressure, went upwards, and the whole interior of the building became subjected to a strong pressure due to the compression of the air. This pressure was more than balanced on the side struck by the wind. On the other sides there was nothing to resist it, and the house was accordingly burst asunder.

We have therefore ample proof of explosion by compression, but none whatever of explosion by rarefaction.

The temperature at the centre is easily calculated. We have assumed, from the data, an average temperature of 76° on the surface of the ground, and a relative humidity of 65 per cent. This gives a dew point of 63°, or thereabout. This sudden decrease of 13°, together with the wet, is sufficient to account for the coolness experienced.

The lowering of the temperature at the centre of the tornado is due to the work performed by the air in expanding under diminishing pressure. The amount of this expansion, and consequently of the diminution of pressure, is easily obtained from the equation $\frac{a+t}{a+t_1} = \left(\frac{v_1}{v}\right)^{k-1}$ ("*Zeuner's Grundzüge*," p. 131), when a = coefficient of expansion = 491, t = initial temperature − 32, t_1 = final temperature − 32, v = initial volume, v_1 = final volume, and k = the relation between the thermal capacities of the air with constant volume, and with constant pressure = 1·41. The initial temperature in the case of the tornado = 76°, and the final temperature 63°. Consequently, $t = 76 - 32 = 44$, and $t_1 = 63 - 32 = 31$. Let us take $v = 1$. Then—

$$\frac{491+44}{491+31} = \left(\frac{v_1}{1}\right)^{1{\cdot}41-1}, \text{ or } \frac{535}{522} = v_1^{\cdot 41}, \text{ or } v_1 = \left(\frac{535}{522}\right)^{\frac{1}{\cdot 41}} =$$
$$= 1{\cdot}8219.$$

A cubic foot of air therefore expands, in passing from the circumference to the centre, to 1·8219 cubic feet. But the pressure is inversely as the volume. Therefore, since the initial pressure was 28·5, $\frac{1 \times 285}{1\cdot 8219}$ = the pressure when the dew point is reached and the funnel commences = 15·69. This gives a diminution of 12·81 inches, corresponding to a pressure of about 6·40 lbs. per square inch, or 922 lbs. per square foot,—an amount of potential energy amply sufficient to account for all the phenomena.

The form and dimensions of the visible funnel did not therefore depend upon the diminution of pressure alone, but also upon the temperature and relative humidity of the inrushing winds. Its presence accordingly does not indicate a certain invariable velocity of the wind. When the air is moist, as it always is over the sea, a very small diminution of pressure, and consequently a comparatively light wind, would suffice to develop the phenomenon of a visible funnel. When, on the contrary, the air is very dry, winds of the utmost possible violence could be produced without a visible funnel. The funnel of dark cloud, therefore, by no means indicates the limits of the ascending current. This renders the explanation of the hovering up and down of the lower end of the funnel easy of comprehension. Varying humidity along the path of the tornado would be sufficient to produce this phenomenon.

As the air ascends the pressure diminishes, and the funnel consequently increases in width. The diminution of pressure perpendicularly is symmetrical, and the result is the symmetry of the form of the funnel.

The Sound.—Its loudness was extreme, yet of such a nature as to drown all other sounds without stunning. A man could stand by his house, as it was shivered to pieces, and not hear the noise of its breaking.

B. Whitaker heard it, together with others, at the distance of 60 miles. He says that even at that distance it indicated great force. The barometric gradient inclined from Mr. Whitaker to the tornado; consequently the propagation of the sound received no help from the wind. Thunder has very seldom been heard at a greater distance than 10 miles. The sound of the tornado was therefore thirty-six times louder than the loudest thunder. Heavy cannonading has been heard, it is said, at the distance of 90 miles, and "the report of a volcano at St. Vincent was heard at Demerara, 300 miles off." The voice of the tornado is, therefore, one of the strongest known to art or nature.

The Tornado in Illinois.—The general appearance of the tornado, as a whole, in Illinois, was somewhat different from that which it presented in Iowa. The ascending column of air was no longer on one side of the centrifugal cloud, but apparently near its centre. Hence the witnesses generally described the cloud as it approached, as consisting of a dark cloud to the north-west, a less dark to the south-west, and a clearer space between. In Iowa all circumstances had combined in order to render precise observation easy. In Illinois the very reverse was the case. I shall therefore treat this portion of the subject in a few general remarks.

The tornado developed energy in this State quite as great as that displayed in Iowa. Its direction of revolution was the same. The disposition of the ruins were precisely similar. It showed the same and even a greater partiality for water-courses, turning abruptly from its course in order to follow them. Its direction varied between north-east and south-east, and was in the main easterly. At the moment when its velocity diminished, and before reaching Spoon River, it passed down close to the whirlwind, and even on its very path a perfect cataract of water. The height of the cloud must have been very great, for it was seen in the west for hours previous to its advent. There was less hail, and the sound was not so generally noticed as in Iowa.

The Identity of the Tornado in Iowa with that in Illinois.— When lost track of, the Iowa tornado was close upon the Iowa river, and travelling to the south-east. Its general course had, however, been easterly. A very severe rain-storm passed over the district between its point of disappearance and the Mississippi River. Trains were delayed by it and bridges washed away. On the Mississippi itself some damage was done to shipping by a violent gust of wind, which accompanied the rain. At Monmouth there was a severe thunderstorm. Twenty miles to the south of it the tornado again struck the ground. It was at Youngstown, at 5.45 P.M., or thereabout. From A. McKee's house, north of Washington, Iowa, to Youngstown, is a distance of about 63 miles in a straight line. The tornado was at McKee's house at 3.10 P.M. The difference between 5.45 and 3.10 is 2.35. The discrepancy due to longitude is four minutes, very nearly. The time, therefore, consumed by the storm in travelling from opposite Washington, Iowa, to Youngstown, Illinois, was two hours thirty-one minutes, or two and a-half hours. $63 \div 2\frac{1}{2} = 25\frac{1}{5}$, which is, therefore, the velocity of the storm, in miles per hour, in a straight line. The length of the journey was materially increased by the crookedness of the path. This brings the velocity nearly up to that with which the meteor traversed Keokuk and Washington Counties, Iowa. These facts, taken in connection, irresistibly lead me to the conclusion that the tornadoes in the two States are one and the same.

The point where the tornado first struck the ground on South Skunk River is situated in 92° 20′ West Longitude and 41° 15′ North Latitude. It was finally lost track of near Peoria, in 89° 37′ West Longitude, and 40° 40′ North Latitude. The whole motion of the tornado, therefore, was 2° 43′ east, and 35′ south, or 143 miles east, and 41 miles south. The mean direction of its path was 24° 51′ south, and 65° 9′ east, and its whole motion 149 miles. The crookedness of its path renders its actual motion considerably greater.

In a late communication Mr. B. Whitaker, correspondent of the Smithsonian Institute of Warsaw and Illinois, states that the elevation of the summit of the cloud was about 18°.

The author thanks Elias Colbert, of the Chicago "Tribune," and the editors of the local newspapers at Washington and Sigourney, Iowa, for assistance rendered, and especially for publishing an extensive list of questions concerning the tornado, which secured for him valuable information from persons residing at a distance.

NOTICES OF BOOKS.

An Elementary Treatise on Steam. By JOHN PERRY, B.E.
London: Macmillan and Co. 1874.

THIS is unquestionably a very useful little text-book, but the author has not altogether done himself full justice in its publication. In the first place the title is ill chosen, as it fails to convey any adequate idea of the real nature of the work. There is one good feature in this little volume which is not generally to be found in publications of a similar character, and this consists in a piecemeal treatment of the subject under consideration; after which examples, or problems, are given, to be worked out by the student in each branch, thus enabling him to ascertain for certain that he has fully comprehended the rules laid down in each case. Mr. Perry acknowledges having received much assistance, in the compilation of this little book, from the treatises of well-known authors in engineering science; but whilst he remarks—not perhaps without reason—on the absence of "experimental and other verification" of many of Prof. Rankine's calculations, there is nothing to show that he has himself attempted any practical verification of them.

This work is divided under four headings, viz.—I. Heat, &c. II. Steam-Engines and Boilers. III. Locomotives. IV. Marine Engines. From the range of subjects thus attempted within the compass of one small volume, it will at once be seen that they can each only be briefly touched upon; and this will be more apparent when it is stated that the important subjects of "Combustion" and "Calorific Power" of Fuel together occupy less than seven pages. In the chapters relating to different kinds of engines, the oft-told tales of their early inventions are again repeated, thus adding to the bulk of the volume without much enhancing its value as a scientific work. In the chapter relating to locomotives about eight pages are given to the subject of "Permanent Way, &c.," which had better have been left out altogether, as it is perfectly impossible to treat properly so important a subject thus briefly. The information regarding "Compound Engines" is scattered over six pages, in different parts of the book. Now this is a subject which is second to none other, when bearing on the question of the economical working of steam-engines, and might well have filled several pages, since to its introduction is due much of the saving of fuel effected in recent steam-engine improvements.

We make these remarks with no wish to injure the reputation of this work, but merely in order to point out where it may be improved should it reach a second edition. On the whole it appears to have been carefully compiled, and is furnished with a useful Appendix of Tables and a good Index; and it will doubtless be found a valuable hand-book for students, to whom we can commend it with confidence.

Our Ironclads and Merchant Ships. By Rear-Admiral E. GARDINER FISHBOURNE, C.B. London: E. & F. N. Spon. 1874.

THIS work is evidently intended as a reply to the principles of Naval Construction as laid down in "Naval Science." The discussions and differences of opinion, which disclose themselves from time to time in our daily and scientific journals, regarding the modern type of war vessels, clearly show that there are two sides to the question as to whether those recently constructed have been built upon proper scientific principles. Now we know that the designs of Mr. Froude and Mr. Reed have long prevailed at the Admiralty, and the Schools of Naval Architecture disseminate the rules laid down by these authorities. Against the principles thus taught Admiral Fishbourne brings forward strong arguments, based upon scientific reasonings, and until his propositions are overthrown by still weightier arguments we shall continue—as we always have done—to have but little faith in the architects of a vessel that will flounder, as did the *Captain*, or that require "so much ballast to make them less dangerous," as the *Sultan* and *Invincible*. In consequence of Mr. Froude's propositions, deep empty spaces in the bottoms of ships were introduced by Mr. Reed, "expressly to facilitate the raising the engines, boilers, and other weights, because it has been ascertained that the tendency of ships to roll has been reduced by these means;" but, as is clearly shown by Admiral Fishbourne, this caused the errors of calculation to be on the *unsafe* side,—that of decreasing the stability below the quantity assigned by it. This principle of construction appears to us to be totally opposed to all previously accepted means of ensuring stability, as is practised, for instance, in the construction of a life-boat, where the spaces are arranged on the sides and ends of the vessel. To construct such deep hollow spaces at the bottom of the vessel must tend to give that part of it increased buoyancy, which, as we have already shown, has to be overcome by a heavy amount of ballast, as would be the case if a boy covered the bottom of his little yacht with cork. The plan adopted of calculating a ship's stability upon the metacentric method in a still basin is justly condemned by our author as not enabling a safe estimate to be made, "because a vessel, when in motion ahead, possesses a greater total stability than her inclination indicates, for it is necessary to provide for sufficient stability when a ship is without motion ahead, and, therefore, without hydrodynamic stability," and he carries his argument out fully to prove that the present metacentric method of calculation is erroneous. The question of buoyancy is next dealt with in a manner which leaves Mr. Reed but little cause to be satisfied with his own performances. In our ironclads great buoyancy is given at the bottom of the vessel, whilst the heavy armour plating on the sides gives weight where buoyancy should exist, for it is at this very point where the life-belt of the ship should be placed. But Admiral Fishbourne is not content with merely stating his arguments at length, but they are supported at length by mathematical calculations which leave no grounds for concluding otherwise than that his theory is based upon true scientific principle.

Practical Solid or Descriptive Geometry. By W. TIMBRELL PIERCE, Architect, late Lecturer on Geometrical Drawing at King's College, London (*vice* Prof. Bradley), and Harrow School. London: Longmans, Green, and Co. 1871.

THIS is a work which has doubtless often been needed by the student of practical solid Geometry. Although many excellent works of this character exist in foreign languages, we have none of a really useful character published in English. A thorough knowledge of the principles of descriptive geometry is needed by many professional men, to enable them to represent solid objects on a plane surface, and hence its application to all the arts of construction, such as architecture, engineering, fortification, &c. To the artist, also, a knowledge of this subject is most important, as enabling him to draw in true perspective, cast the shadows of objects truly, and obtain the true position of the *locus* of greatest light on an object.

The first part of this work treats on orthographic projection, and is divided into six chapters as follows:—I. Definitions, &c.; Projections of Points and Lines. II. On Straight Lines and Planes. III. The Five Regular Solids, viz., the Tetrahedron, the Cube, the Octohedron, the Dodecahedron, and the Icosahedron. IV. Consists of Examples and Problems illustrating the principles of construction contained in the preceding chapters. V. On Section Planes and the Intersections of Solids. VI. On Tangent Planes and Surfaces in Contact.

The second part of the book is on Perspective, or Radial Projection, which is the application of the principles, enunciated in the first part, to practice on a plane surface: their application to the several arts of construction is a further development of the subject, which Mr. Pierce promises to explain in a future work. The careful manner in which the student is gradually advanced from one point to another, through the pages of this book, must render it one of great value to the student as a text-book, whilst the manner in which it has been got up leaves nothing to be desired: it is printed in a good bold type, and illustrated with thirty-seven plates carefully drawn and clearly lettered.

Results of an Experimental Enquiry into the Mechanical Properties of Steel of Different Degrees of Hardness, and under Various Conditions, Manufactured by Charles Aspelin, Esq., Westanfors and Fagersta Works, Sweden. By DAVID KIRKALDY. London: published by the Author. 1873.

WITHIN the last few years a revolution has been gradually effected in constructive art by the introduction of a material which combines, in an eminent degree, strength, hardness, and toughness, and which admits, according to its mode of preparation, of great variations in its physical properties, and is therefore applicable to a vast variety of purposes. As the applications of steel are constantly being extended, it becomes a matter of great importance to the mechanical, civil, and mining engineer that the physical properties of the material should be accurately determined. Few men are better qualified to conduct such enquiries than is Mr. Kirkaldy. His great experience in testing the mechanical properties of metals is the best guarantee that his tests are judiciously applied, and the results intelligently interpreted.

In the present work Mr. Kirkaldy gives the results of an elaborate enquiry into the physical characters of a large number of samples of Swedish steel, made at Fagersta. Some of these tested specimens were sent to the Paris Exhibition of 1867, but the greater number were prepared for the late Vienna Exhibition. The results exhibit the behaviour of the metal when subjected to pulling, thrusting, bending, twisting, and shearing strains; in fact, when tortured in every way that can possibly be of interest to the engineer. These results are exhibited in a series of carefully-arranged tables, which, although of great value for reference, are not of course attractive to the reader. They deserve, however, to be carefully studied by all who are interested in the manufacture and applications of modern steel.

Annual Record of Science and Industry for 1873. Edited by SPENCER F. BAIRD. New York: Harper Brothers.

THIS work, which has now reached its third year, is in its general objects similar to the "Year-Book of Facts." It has, however, certain unmistakable advantages over its English contemporary, Its information is not drawn from ordinary newspapers.

The scientific and technological journals of France, Germany, Holland, Switzerland, Italy, and Denmark, as well as of America and England, have been carefully laid under contribution. Hence paragraphs found in this volume may be quoted or appealed to with a reasonable amount of confidence. Another useful feature is, that not merely the names of the journals quoted are given, but the date and the page, so that it is easy to verify any citation, or, in case of on abstract, to find full particulars. That such an arrangement much enhances the value of any work of this class is obvious. The classification is also natural, or scientific, which is the same thing.

To an Englishman, perhaps the most interesting feature of the book will be found in the notices of various American institutions for the promotion of science. In this respect we cannot help expressing the fear that America is evincing greater energy, greater liberality, than ourselves. Of this we find many instances. The museum at Yale College has secured the finest specimen of the pterodactyl ever discovered. The British Museum was negotiating for the purchase, but our rivals over the Atlantic telegraphed to the owner to name his price, and paid it. What have we in England equivalent to the Stevens Institute of Technology at Hoboken, founded, it must be remembered, by the munificence of a private individual? How few instances do we hear in England of bequests or donations to museums, free public libraries, and institutions for training up discoverers and inventors! The liberality of our wealthy men seems to take every channel rather than this. We do not at all think that in natural aptitude for the successful study of Science the British and Irish nations are inferior to any people on the globe. But supremacy in this respect, just as in war, can no longer be attained by the spontaneous and desultory efforts of individuals. General, systematic, persistent action is wanted. Original research has to be conducted on a changed ground, and can no longer, as in the days of Scheele, or even of Davy, be effected with a few phials, tobacco-pipes, gallipots, and saucers. The influences which Decandolle finds most powerful in "advancing science, by increasing the number of those who prosecute it in the right spirit, are, *first*, a well-organised system of instruction, *independent of parties*, tending to awaken research and to assist young persons devoting themselves to science; *second*, abundant and well-organised material means for scientific work, libraries, observatories, laboratories, collections, &c.; *third*, freedom of utterance, and publication of any opinion on scientific subjects without grave inconvenience." To what extent are these influences at work among us? We have museums; some of them placed where they are accessible to few but fashionable idlers; others carefully closed in the evening, on public holidays, and, in fact, at every time save what are called "hours of business." We have libraries open to the same charges, whilst the formation of establishments of this kind under Mr, Ewart's Act has been opposed—and in too many instances successfully—by the interests now dominant in the House of Commons. Our "system of instruction," if "organised" at all, seems arranged rather for the aggrandisement of parties and interests than for training up thinkers and discoverers. Did not Lord Sandon, in his place in Parliament, lately oppose a project for extending the curriculum of elementary education, by asserting that the purpose of the movement was to "crowd out" theological teaching? Instead of regaining the ground we have lost in competition with foreign nations, it may be gravely questioned whether we are not falling further and further into the rear. This is a melancholy prospect for those who are aware of what is going on, and who find their words of warning drowned amidst the uproar of the "interests."

Legal Responsibility in Old Age. By G. M. Beard, A.M., M.D., New York: Russell.

The title of this thoughtful, interesting work is far from conveying a full idea of its nature and contents. There is a very common notion that the mind attains its maximum development long after the maturity of the body; often, even, after the vigour of the latter is plainly on the decline. Hence wisdom is regarded as no less a normal attribute of old age than is strength of youth. This view the author has subjected to a careful criticism, and, as the conclusion of his researches, has pronounced it unwarranted by facts. His method—the only one applicable in the case—has been to prepare "a list embracing nearly all of the greatest names of history whose lives are recorded in sufficient detail to be of value in such an investigation," and to note "the age at which they did the original work by which they have gained their fame." From a comparison of these data he has deduced "the period, the decade, and the year of maximum productiveness, and the various grades between this and the period, the decade, and the years of the least productiveness." The enquiry has been extended to great men of all departments, scientific, artistic, and practical.

As a general result, the author finds that 70 per cent of the work of the world is done before the age of 45, and 80 per cent before that of 50. Going into more exact detail, Dr. Beard divides the active portion of human life into six decades:—

The golden	decade	is between	30 and 40.
The silver	,,	,,	40 and 50.
The brazen	,,	,,	20 and 30.
The iron	,,	,,	50 and 60.
The tin	,,	,,	60 and 70.
The wooden	,,	,,	70 and 80.

"The golden decade alone represents nearly one-third of the work of the world, and nearly 25 per cent more dates than the silver. The best period of fifteen years is between 30 and 45. The advantage of the brazen over the iron decade is very striking, and will cause surprise. There is considerably more work done between 35 and 40 than between 40 and 45." Dr. Beard, we may observe, is not particularly happy in the selection of metals to illustrate the comparative value of the respective decades of life. Tin, for instance, may reach fifty times the value of iron.

It may be urged that many men of genius die young, and that, possibly, if not thus prematurely cut off, they might have continued to distinguish themselves up to an advanced time of life. This objection the author anticipates by remarking that "the average age of the great personages from whose lives the law is derived is not far from 66 years." He continues—"On the average the last *twenty* years in the lives of original geniuses are unproductive." "The broad fact, then, to which these statistics lead us is that the brain follows the same line of growth, maturity, and decay as the rest of the body; that the nervous, muscular, and osseous systems rise, remain, and fall together, and that the received opinion that the mind—of which the brain is the organ—developes and matures later than the power of motion, or of physical labour and endurance, is not sustained by the facts of history."

Having thus stated his general conclusion, the author takes into consideration qualifying circumstances and exceptions. He points out the distinction between *original* work, requiring enthusiasm, and *routine* work, depending on experience. The former he considers the especial province of the young, and the latter of the old. "The people unconsciously recognise this distinction between the work that demands enthusiasm and that which demands experience, for they prefer old doctors and lawyers, while in the clerical profession—where success depends on the ability to constantly originate and express thought—young men are the more popular, and old men, even of great ability, are shelved or neglected." Here we may remark that in England, and still more on the Continent, the clerical profession is far from being the one from which originality of thought is most urgently demanded. The faculty of expression often seems to survive the power of origination. Thus the "old man eloquent" may often, in the evening of his days, embody in words and give to the world the ideas which he had thought out in the days of his prime. "The most marked exceptions to the law are found in the realm of imagination; some of the greatest poets, painters, and sculptors have done a part of their very best work in advanced life." We might here, however, ask—whether enthusiasm is not at least as necessary in the elaboration of an epos, a drama, or a painting, as in that of a scientific theory or a patent?

The following passage is of profound significance:—"Children born of parents one or both of whom are between 25 and 40 are, on the average, stronger and smarter than those born of parents one or both of whom are much younger or older than this." Political economists, we believe, claim the privilege of being ignorant of every science except their own, and in virtue of that ignorance they counsel late marriages, in the hope of checking the too rapid increase of population. Unfortunately their scheme reduces not merely the number, but the stamina, physical and mental, of a nation.

Dr. Beard next examines the moral faculties, and finds them subject to the same law. "It does not follow," says he, "that when a man declines in moral principle that he necessarily becomes a horse-thief—a loss of active moral enthusiasm is frequently all that is noticed." Among the causes of moral decline in old age the author enumerates—"Over-exercise through life of the lower at the expense of the higher nature; disease of the brain, or of other parts of the body that react upon the brain, and intellectual decline." "Death," he remarks, "is more frequently a process than an event. When conscience is gone the constitution may soon follow." In illustration of the decline of the moral faculties in old age, we are referred to the lives of a number of historical characters, among whom figure the names of Carlyle and Ruskin. A note on the death of Agassiz must not be overlooked:—"To his friends it is well known that Agassiz began to die several years ago. His death can be hardly regarded as a loss to scientific research, for he had long ceased to be productive. So far as he lives in the future of science, it will be mainly for the original work that he did before he reached his fortieth year. The intemperate manner of his opposition to the theory of evolution, by which he was so rapidly winning favour among the thoughtless and ignorant, and so rapidly losing favour among the conscientious and scholarly, may find its partial—if not complete—explanation in the exhausted condition of his brain."

We are here reminded of those changes of opinion on controverted points—theological, political, or philosophical—which eminent men sometimes experience in the decline of life. The old friends of such a character seldom fail to denounce him as a pervert and a renegade, and to accuse him of corrupt motives. Those whom he has just joined hail him a convert, and rejoice that his eyes have at last been opened to the truth. Both are wrong. Such changes are often sincere, but they spring not from illumination, but from a darkening of mental vision. The accession of a man, once great, who has fallen into second childhood, is no great triumph to any party. What matters it if, in his declining years, Liebig showed leanings to Obscurantism? One of the most ordinary phases of mental decay is the mingled incapacity and unwillingness to recognise new discoveries or new ideas. We have seen it somewhere stated that no physician who had reached the age of 50, at the time when Harvey made public his discovery of the circulation of the blood, could ever be induced to give it his recognition. Dr. Oliver Wendell Holmes, one of the most original thinkers that America has produced, says—"New ideas build their nests in young brains; revolutions are not made by men in spectacles, as I have heard it remarked; and the whisperings of new truths are not caught by those who begin to feel the need of an ear-trumpet."

We have thus far expounded Dr. Beard's opinions, and we fully admit their value. The evidence he has brought forward to prove that early life is the season for original work scarcely admits of doubt; but we still question whether the development and the decline of the various faculties of the human system are so strictly synchronous as he maintains. We have known a man of powerful frame and active habits, who, in the sixties, had become quite childish, and "babbled o' green fields" in a style very unedifying; yet his pedestrian powers were the envy of many men on the sunny side of 40. Conversely, our readers will doubtless recall cases of men, physically feeble, but yet retaining their memory and their reasoning powers, little, if at all, impaired. It seems to us that if any faculty is naturally strong, and has been judiciously cultivated, it will preserve its vigour after the system in other respects shows manifest symptoms of decay.

Into the application of the doctrines above explained to forensic medicine and to jurisprudence we do not propose to enter. The author raises the questions—"To what extent is the average responsibility of men impaired by the change that the mental faculties undergo in old age?" And—"How shall the effects of age on the mental faculties be best brought to the attention of our courts of justice?" That these questions will have to be taken into account by the legislation of the future is undeniable.

The Year-Book of Facts in Science and Art. By John Timbs. London: Lockwood and Co.

This annual still pursues the even tenour of its way, giving a yearly summary of discoveries, inventions, and what are supposed to be the most important facts connected with science and industrial art. The utility of such a work is indisputable, and that it meets a recognised want may be inferred from the fact that it has regularly appeared for a quarter of a century. We cannot, however, but regret that much matter is inserted on authority which the scientific public can scarcely recognise. The origin of many of the paragraphs and extracts is not stated, whilst very many others are drawn from ordinary newspapers, English and American. Now the inaccuracy of the scientific information given in such journals, from the "Times" downwards, is a matter of notoriety. Indeed, strictly scientific papers, English or foreign, appear to have been eschewed by the editor. In the section on Chemistry, which extends to no more than eleven pages, we find extracts from the "Times" and the "Illustrated London News," but not a passage from Liebig's "Annalen," from the "Berichte" of the German Chemical Society, or the "Chemical News." A similar complaint might be made concerning the chapters on Zoology and Botany, where among the authorities figure the "Homeward Mail, the "Globe," the "Pall Mall Gazette," and the "Grocer."

As regards the classification of the matter, the editor appears to proceed on principles of his own. Thus under the head "Chemical Science," we find paragraphs on "Sunlight for the Sick," on "Prompt Remedies for Accidents and Poisons," and on "Opium Smoking in New York!" On the other hand, "Butter and its Adulterations" and "Tea and its Adulterations" rank under "Mechanical and Useful Arts." On the other hand, we find an article on "Compressed Peat"—abridged from the "Times"—in the chapter on Geology and Mineralogy.

But the gravest complaint against this compilation is the very small amount of light which it throws upon the progress of the sciences, and upon their practical and industrial applications. An intelligent man, without any especial acquaintance with chemistry, would, from merely reading Mr. Timbs's "Year-Book," be utterly unable to form any adequate idea of the part which that science is now playing in the development of civilisation. We make these remarks not in a captious or "hyper-critical" spirit, but in the hope that the defects we point out may be in future amended, and that the work may be made—as it easily could—useful to the pubic, and a credit to our technological literature.

The Treasury of Natural History; or, a Popular Dictionary of Zoology. By SAMUEL MAUNDER. Revised and Corrected, with an Extra Supplement. By E. W. H. HOLDSWORTH. London: Longmans, Green, and Co.

THIS compact volume, as far as its size allows, gives a clear and generally correct account of the orders, families, and genera, as well as of the more important species of the animal world. The illustrations are numerous. We do not agree with the description given of the common viper. The ground colour of the male is said to be a dirty yellow; that of the female deeper. Among the numbers we have seen the males were of a pale ash-grey, and the females of a decided copper colour. We cannot help expressing our dislike of the very minute type which has been selected. Surely economy in cost and bulk is purchased too dearly at the risk of impaired eyesight. The syllabus of Practical Taxidermy will be found very useful to incipient naturalists.

United States Commission on Fish and Fisheries. Commissioners' Report, 1871-1872. *The Fisheries of the South Coast of New England*. Washington: Government Printing Office.

THIS is a most elaborate "Blue Book," extending to 850 pages, and abundantly illustrated. The condition of American fisheries, the arguments in favour of their regulation by law, the reports of state commissions and of European authorities on this subject are given with great minuteness. We find also a description of the various kinds of apparatus used in capturing fish on the sea-coast and lakes of the United States, and of patents granted to the end of 1872 for inventions relative to the capture, utilisation, or cultivation of fish and marine animals.

The greater part of the volume, however,—and this is a feature to which we desire to call special attention,—is taken up with matter specially interesting to the naturalist. There is a report of Dr. Farlow on the sea-weeds of the south coast of New England, and one by Mr. A. E. Verrill on the invertebrate animals of Vineyard Sound and the adjacent waters, with an account of the physical characters of the region. We must call particular attention to the list of species found in the stomach of fishes, as throwing a valuable light on their food, and to a paper on the metamorphoses of the lobster and other crustaceans. Mr. Theodore Gill's catalogue of the fishes found on the east coast of North America, and Mr. S. F. Baird's list of fishes collected at Wood's Hole Harbour, with the table of temperatures for the year 1873, also furnish valuable data for the student of marine zoology. Very curious are the quaint reports on the fauna, terrestrial as well as aquatic, of New England and the other Atlantic Districts in the old colonial days. A "squiril" is described as "red, and he haunts our houses, and will rob us of our Corne, but the Catt many times payes him the price of his presumption." Here is a hint which we commend to the professors of cookery at South Kensington:—"We used to qualifie a pickled *Herrin* by boiling of him in milk." Scientific controversy was, in those days, carried on with some disregard of courtesy. "One writes that the fat in the bone of a Basse's head is is braines, which is a lye."

The whole volume is highly creditable to its compilers as well as to the Government which has ordered its publication.

PROGRESS IN SCIENCE.

MINING.

In consequence of the great development of the manufacture of spiegeleisen, both in this country and on the Continent, the spathic iron ores, or native carbonates of iron, which are so largely used in this manufacture, have been brought, within the last few years, very prominently into notice. A paper on the distribution of these ores was read by Mr. C. Smith at the recent meeting of the Iron and Steel Institute. In this country there are numerous deposits of spathose ores, the most important perhaps being those of the Brendon Hills, which are worked by the Ebbw Vale Company. Here the ores occur in irregular veins, coursing through Devonian clay-slates, and recalling the conditions under which similar ores occur in Rhenish Prussia. The spathic ores of the Rhine Provinces are distributed in two separate districts—the one near Coblenz, and the other to the east of Cologne; the latter being by far the larger area, and containing the well-known Stahlberg. In Styria immense deposits of spathic ores have long been worked, especially at the Eisenerz, for the manufacture of charcoal-iron. Sweden seems to be destitute of these ores, the magnificent iron-making resources of that country consisting mainly of magnetites and red hæmatites. The mineral called Knebelite—a silicate of iron and manganese—is worked in Sweden for use in the spiegeleisen manufacture.

Some deposits of tin-ore, which promise to become of enormous value, have been discovered at Mount Bischoff, in Tasmania. We believe that Mr. Gould, the Government geologist, who has recently returned from Tasmania, bringing with him some fine examples of these ores, will shortly communicate a description of the deposits to the Geological Society. Some of the tin-stuff is associated with much ochreous oxide of iron. In addition to the lodes, there are said to be alluvial deposits of vast magnitude. Mr. W. Ritchie speaks of one bed of wash-dirt, 37 feet in thickness, rich in tin from the surface to the bottom of the shaft.

A rapid tour through Gippsland, made in the early part of this year, has enabled Mr. R. Brough Smyth to contribute to a recently-issued official Report some remarks on the mineral resources of this part of the Colony of Victoria. Many parts of the country are said to be rich in gold, but though some few workings—such as the Walhalla mines—have been for some years in operation, the gold-fields of Gippsland have yet to be developed.

From Persia we hear of recent discoveries of several beds of coal, and of deposits of nickel ores, by Dr. Tietze, of Vienna, who is now engaged in exploring this country with special reference to its minerals. The coal is said to be of Mesozoic or Secondary age. Much of the coal of Queensland, and valuable deposits of mineral fuel elsewhere, are also referable to the Mesozoic period.

With reference to the age of some of the American coals and lignites, Dr. J. S. Newberry has recently communicated to "Silliman's Journal" a paper in which he takes a general review of the occurrence of coal in the Far West, and seeks to show that the deposits of lignite and the various plant-beds of the Western States are mostly of Cretaceous age, whilst some belong to the miocene period. The coal of Vancouver's Island is said to be Cretaceous.

A deposit of bismuth ore has been discovered near Meymac, in the Department of the Corrèze, in Central France. The ore occurs in a quartzose vein running through granite, and is accompanied by wolfram, mispickel, and pyrites. The bismuth exists chiefly as the native metal, but partly as sulphide and as oxide.

The first volume of the "Transactions of the American Institute of Mining Engineers" has been recently published in Philadelphia. This volume contains a rich collection of papers on mining and metallurgy, selected from communications made to the Institute since its foundation in 1871.

METALLURGY.

No one will be disposed to question the good sense of the governing body of the Iron and Steel Institute in awarding the first Bessemer medal to Mr. I. Lowthian Bell, as a fit recognition of his services to the science and practice of iron-smelting.

In delivering the Presidential Address at the recent meeting of the Institute, Mr. Bell referred to the advance of mechanical puddling in this country, at the same time expressing his fear that at present the success of Danks's system had hardly been found equal to what might have been expected from the Report of the Commissioners appointed by the Institute to examine into the working of this system in America. Danks's furnaces have now been erected by Messrs. Bolchow and Vaughan, Messrs. Hopkins, Gilkes, and Co., the Erimus Iron Company, and the North of England Industrial Iron Company, whilst in North Staffordshire they have been introduced by Mr. R. Heath. It is therefore to be expected that we may soon have opportunity of thoroughly testing the practical value of this system of puddling. Mr. J. A. Jones, who has had perhaps more experience than any one else on this subject, contends that the Danks principle is perfectly sound, and merely requires development, and perhaps a little mechanical modification, to make it commercially a success. He maintains, indeed, that a few months hence we shall be able to turn out better bars, cheaper by the rotatory furnace than by the old method of manipulation. It has been said that the Danks furnace is, from a mechanical point of view, a complete failure, but the details of construction may be easily modified without affecting the general principle. At the Erimus Works a furnace is to be erected which will combine some of the principles of the Danks with those of the Crompton furnace. Mr. Crompton's furnace, in which finely-divided fuel is introduced with the blast, has been working with great success at Woolwich.

A mechanical puddling-furnace of peculiar construction, devised by M. Pernot, has been worked by MM. Petin and Gaudet, at St. Charmond. The puddler is an iron bowl, mounted on a cast-iron carriage, which is caused to rotate by machinery. The bloom may be divided into as many portions as may be desired, instead of being limited to a single large ball. The iron is said to be of high quality, while the mechanical arrangements admit of being applied to existing plant.

Spiegeleisen formed the subject of an interesting paper communicated to the Iron and Steel Institute by Mr. G. J. Snelus. This paper was intended to supplement Mr. Forbes's valuable "Report on the Manufacture of Spiegeleisen on the Continent," published some time ago in the Journal of the Institute. The use of spiegeleisen, originally suggested by Mr. Mushet, was worked out by Mr. Bessemer, and its manufacture has now become an important branch of manufacture even in this country. Instead of relying for our supply, as formerly, upon the Continent, we have found ores suitable for its production, and have established its manufacture at Ebbw Vale, at the Landore Steel Works, at Dowlais, at Middlesbro', at Sheffield, and in Cumberland.

Attention has been recently called to the part which silicon plays in pig-iron during its conversion in the Bessemer process. By oxidation in the converter, the silicon is converted into silica, which passes into the slag, and during this oxidation a much greater quantity of heat is evolved than could be obtained by the oxidation of an equal weight of carbon. According to the experiments of Troost and Hautefeuille, the carbon of cast-iron, at a temperature above that of the fusion of the metal, reduces silica, the silicon replacing the carbon in the pig.

Some experiments have been made by Mr. C. H. Morton on the condition in which silicon exists in pig-iron. The experiments were made on a No. 1 Bessemer pig, containing 4·612 per cent of silicon. They tended to show that the silicon does not exist in a free state mechanically associated with the iron, but rather in a combined form as a definite silicide of iron, just as carbon may exist as a carbide; the silicon does not appear, however, to assume a graphitoidal form in the iron, corresponding with the uncombined carbon of cast-iron.

In recently describing a mass of meteoric iron from Howard Co., Indiana, Dr. J. Lawrence Smith takes occasion to make some general remarks on iron, which are not without interest to the metallurgist. The Indiana iron appears to be a true meteorite; it contains 12·29 per cent of nickel, 0·65 of cobalt, and 0·02 of phosphorus; yet when a polished face is acted on by acids it does not exhibit the well-known Widmannstättian figures. Some authorities have maintained that these markings result from the accumulation of an alloy richer in nickel than the mass of the iron; whilst others have referred them to a definite phosphide of iron and nickel, accumulated along certain lines of crystallisation. Neither of these theories, however, satisfactorily accounts for their presence in some irons and their absence from others. Dr. Smith believes that in the solidification and crystallisation of iron there is a tendency to eliminate the foreign constituents to the exterior of the crystals. If, then, a meteoric mass has consolidated rapidly, the phosphorus might be so diffused as to afford no marked indication of its presence, but if consolidated slowly there would be a more or less perfect elimination of the phosphorus in parts representing spaces between the crystals of the mass. We may remark, in passing, that Dr. Smith has found that the presence of 1 per cent of phosphorus, or less, in cast-iron, enables the metal to resist the action of concentrated sulphuric acid to a greater degree than when the metal is entirely free from phosphorus.

Natro-metallurgy is a term applied to a process for refining impure lead, recently introduced by MM. Payen and Roux, of Marseilles. The foreign metals present in the hard lead are removed by means of molten caustic soda, the oxidation being facilitated by the introduction of jets of steam, a blast of air, or addition of nitrate of soda.

Some notes on the metallurgy of bismuth have been communicated to the "Annales de Chimie" by M. A. Valenciennes, who describes the process which he has introduced at St. Denis for working the Bolivian ores. Having been first roasted in a reverberatory furnace, the ore is mixed with 3 per cent of charcoal and a flux composed of lime, soda, and fluor-spar. After reduction the products separate in order of density—at bottom a button of bismuth, above this a regulus of sulphides of bismuth and copper, and on the top a vitreous slag containing silicate of iron. The crude bismuth contains about 2 per cent of antimony and lead, and about the same proportion of copper, with traces of silver. If used for preparation of subnitrate, the bismuth is fused with nitre, to oxidise the antimony, whilst the other foreign metals are separated by the wet way. The regulus may be roasted, and subjected to similar treatment as the original ore. In treating the French bismuth-ores recently discovered at Meymac recourse is had to a wet process. The finely-divided ore is digested in hydrochloric acid, the solution neutralised, and water added, whereby a subchloride is precipitated, and this precipitate is then reduced by contact with metallic iron. The bismuth thus obtained is dried, and fused with an alkaline flux. A similar mode of treating the French ores has been carried out by M. Carnot.

Dr. Laspeyres, of Aix-la-Chapelle, has contributed to the "Journal für Praktische Chemie" a description of some artificial crystals of metallic antimony, accidentally obtained in slags at the Münsterbusch Lead-Works, near Stolberg. Some antimonial residues and lead slags were smelted in a blast-furnace, with the view of obtaining a hard lead rich in antimony. The crystals appear at first sight to be regular cubes, resembling the well-known artificial galena, but are really rhombohedra of nearly 90°, combined with the basal planes, and in some cases twinned so as to exhibit the characteristic re-entering angles.

MINERALOGY.

A mineralogical paper of considerable interest has been communicated to the American Academy of Arts and Sciences by Prof. J. P. Cooke, jun., in which he reviews the history of those micaceous minerals which may be grouped together under the general name of *Vermiculite*. This name was originally applied by Mr. T. H. Webb to a peculiar mineral which at the time of its discovery excited much interest by its curious behaviour when heated; the substance exfoliated prodigiously, and the little scales opened out in worm-like threads, which suggested the original name. This remarkable exfoliation and the apparent increase in volume are referred by Prof. Cooke to the loss of water of crystallisation, and may be compared with the well-known efflorescent phenomena presented by the dehydration of certain crystalline salts. Other minerals possessing similar pyrognostic characters have since been discovered, and a comparison of these minerals has led the author to extend the use of Vermiculite as a family name. Three distinct species are now included in this group: first, *Jefferisite*, a mineral discovered by Mr. W. Jefferis at West Chester, Pa., and described by Prof. Brush; secondly, *Hallite*, a new species founded by Prof. Cooke on specimens collected by Mr. J. Hall at East Nottingham, Chester Co., Pa.; and thirdly, *Culsageeite*, another new species discovered in Col. Jenks's Culsagee Mine in North Carolina, which mine has yielded the remarkable specimens of corundum noticed in our report last quarter. Prof. Cooke discusses in much detail the crystallographic, optical, and chemical characters of Jefferisite, Hallite, and Culsageeite, with special reference to their relation to the group of micas.

Our knowledge of the mineralogy of the Argentine Republic is much increased by a paper recently communicated to Tschermak's "Mineralogische Mittheilungen" by Dr. A. Stelzner, who was appointed a few years ago Professor of Mineralogy in the University of Cordoba. The Sierra of Cordoba, rising like an island from the surrounding pampas, is composed of three parallel ridges, which consist principally of crystalline slates associated with masses of granite in which are large quartz-stocks containing minerals of considerable interest. Although consisting chiefly of quartz, these stocks invariably contain mica, as well as large crystals of orthoclase-felspar. Beryl is also found in six-sided prisms of unusual size, whilst apatite and triplite occur subordinately. But the most interesting of this group is the rare mineral columbite, specimens of which have been analysed in Cordoba by Dr. Siewert. Another series of minerals described by Stelzner occurs in crystalline limestones, associated with the metamorphic rocks of the Sierra.

Prof. A. H. Church has communicated to the "Chemical News" his analysis of Ashantee gold. Those who are familar with the fine collection of nuggets and ornamental objects lately exhibited by Messrs. Garrard will remember that most of the specimens presented a rich colour, heightened by association with a red ferruginous earth, more or less adherent to the surface. Church's analysis gave—Gold, 90·055; silver, 9·940; iron and copper, traces.

The same chemist has also published in the "Chemical News" his analysis of some clean grain-gold from a burn at Wanlock-head in Dumfriesshire. A good deal of historical interest clings to the gold-fields of Southern Scotland, though well-nigh forgotten at the present day. Worked by Sir Bevis Bulmer in the sixteenth century, they yielded the gold from which the unicorns and the bonnet-pieces of James IV. and V. were coined. It was these mines, too, that were at one time to be worked by a company of twenty-four gentlemen to be created "Knights of the Gold Mines." At present, however, the Clydesdale washings yield only specimens for the cabinets of the curious. Prof. Church finds the Wanlock-head gold to contain—Gold, 86·60; silver, 12·39; iron, 0·35. A specimen of Sutherlandshire gold has yielded to Mr. G. H. Makins 79·22 per cent of gold and 20·78 per cent of silver. Pliny tells us that when the proportion of silver in gold exceds one-fifth, the substance is called *electrum*. According, then, to this definition, which is still adhered to by some mineralogists, the Sutherland gold is an electrum.

Two specimens of what appeared to be native silver have been analysed by Prof. Church, and the results published in the "Chemical News." Both came from Allemont, in Dauphiny, and were formerly in Heuland's collection. One contained—Silver, 71·69; mercury, 26·15; antimony and traces of arsenic, 2·16. The other contained—Silver, 73·39; mercury, 18·34; antimony and arsenic, 8·27. These figures do not correspond precisely with analyses of any *native amalgams*, nor with the antimonial silvers called *dyscrasite*, the latter being always regarded as non-mercurial.

Although the Jubilee volume of "Poggendorff's Annalen," which has recently been issued in commemoration of the fiftieth year of its publication, is for the most part devoted to memoirs on the several branches of physical science, it is nevertheless of considerable interest to the mineralogist. Prof. Rammelsberg gives a masterly sketch of the history of the Chemistry of Minerals during the last half century: Vom Rath publishes some valuable crystallographic studies; and Hankel gives a *resumé* of his researches on the pyro-electricity of certain minerals. In the same volume Dr. T. Scheerer has a paper "On the Formation of the Minerals which accompany Ores." His investigations relate to the conditions under which the most common non-metallic minerals of lodes—calc-spar, quartz, barytes, and fluor-spar—have been produced. As these may be formed in the wet way, and have probably been so formed in nature, it is only rational to conclude that the ores which accompany them in mineral veins owe their genesis to similar causes.

Two kinds of pseudomorphs after rock-salt have been discovered in sinking shafts for working some deposits of salt at Westeregeln, near Stassfurt, in Prussia. In one case we have a curious example of rock-salt pseudomorphous after rock-salt, whose formation may be thus explained: chloride of sodium was originally crystallised in cubic forms in a matrix of soft clay; the crystals were then dissolved, leaving cubic cavities, which were afterwards more or less distorted by movement of the surrounding clay; the walls of the cavities were next lined by a thin coating of quartz-crystals; and, finally, the drusy cavities became occupied by a second deposit of salt, which thus assumes abnormal forms and presents the curious feature of cleavage not necessarily parallel to faces of the crystal, since the internal structure bears no relation to external form.

The other Westeregeln pseudomorphs are six-sided crystals, like those of carnallite, but composed almost exclusively of chloride of sodium. Both kinds may be found in the same hand-specimen.

Under the name of *Rhagite*, Prof. Weisbach has recently described a hydrous arsenate of bismuth, discovered among the new uranium ores at Schneeberg, in Saxony. The name was suggested by the botryoidal form and grape-green colour of the mineral.

A description of a new Mexican mineral has been communicated by Don Ant. del Castillo to the Journal "La Naturaleza." The mineral is said to be a double selenide of bismuth and zinc.

The name of *Huantajayite* has been bestowed upon a Peruvian mineral by M. Raymondi, of Lima. Its composition seems peculiar; it is said to be a double chloride of sodium and silver, containing 89 per cent of the former and 11 of the latter salt. It occurs in small colourless cubes, associated with the chloride and chloro-bromide of silver and oxychloride of copper. This occurrence would seem to show that the metallic chlorides and bromides in Peru may owe their origin to the action of sea-water on the minerals of the lodes.

Grochauite is the name which Dr. Websky proposes for a new species closely related to clinochlore, occurring in serpentine at Grochau in Silesia. It is associated with an ore of chromium described by Dr. Bock as *Magnochromite*, which appears to be a member of the spinel group, rich in magnesia.

Websky has recently analysed the mineral called *Strigovite*, which occurs in granite at Striegan in Silesia.

A mineral resembling chalcomorphite has been found in limestone enclosed in the lavas of Ettringen, near the Lake of Laach, and has been recently described by Herr J. Lehmann as *Ettringite*.

The extremely rare mineral *Osm-iridium*, an alloy of osmium and iridium, has been discovered in small quantity near Stockyard Creek, Gippsland, in the Colony of Victoria.

Prof. Rammelsberg has communicated to the German Geological Society, at Berlin, several new analyses of *Idocrase*, or *Vesuvian*, accompanied by a review of our knowledge of the chemical composition of this species.

Some notable examples of the occurrence of crystals of quartz have been collected by Dr. Websky, and described in a crystallographic paper published in Leonhard and Bronn's "Jahrbuch."

ENGINEERING—CIVIL AND MECHANICAL.

Guns.—A paper of some importance at the present time, when the size of guns is growing so rapidly, was recently read before the Institution of Civil Engineers, by Mr. G. W. Rendel, on "Gun-Carriages, and Mechanical Appliances for Working Heavy Ordnance." Owing to the increase in the power and size of ordnance since the introduction of armour, gun-carriages have gradually become elaborate machines, and the appliances for working the monster ordnance now in contemplation will tax all the resources of mechanical science. The first difficulty experienced in mounting the Armstrong rifled guns arose from the much greater violence of their recoil as compared with that of the old cast-iron guns, a disadvantage mainly resulting from their superiority in lightness, strength for strength. After describing a self-acting brake for arresting recoil, designed and successfully tried at Elswick in 1864, reference was made to the great superiority of wrought-iron over timber as a material for gun-carriages, and experiments made in 1865 were cited as showing the error of the popular objection entertained against wrought-iron on the score of its producing, when struck by shot, more numerous and destructive splinters than timber. By the adoption of mechanical arrangements for the application of manual power to the working of ordnance, guns up to 25 tons weight can now be worked with more ease, safety, and rapidity than guns of a fifth of that weight were formerly worked. Guns. however, are now being made of nearly double that weight, and hence the adoption of some inanimate power, in the place of mere hand labour, for loading and working heavy ordnance, has become an absolute necessity for guns of the future. The simplicity and compactness of hydraulic machinery, and the perfect control it gives over heavy weights, especially adapts it for the purpose. Hydraulic power sufficient for the heaviest gun may be transmitted through a very small tube for long distances and by intricate ways, so that a steam-pumping engine may be placed in a fort or ship in such a position as to be absolutely secure, and supply power by this means for working many guns. The arrangements for loading and working guns by hydraulic machinery embrace a new system of mounting turret-guns, in which the carriage is dispensed with, and the gun is supported on three points, viz., on a pair of trunnions placed well forward, and on a saddle under the breech itself. The trunnion-arms rest in two sliding-blocks, which run in guides on fixed beams, built on the floor of the turret; and immediately behind each block, in the direct line of recoil, are two hydraulic cylinders for checking recoil and running the gun in or out, whilst the saddle which supports the breech slides along a beam or table beneath it. The front of the beam can be raised or lowered by a hydraulic press to give any desired elevation, but the rear is pivoted at a point corresponding to the horizontal position of the gun; consequently it always returns to the horizontal position as it recoils, whatever elevation it may be fired with, clearing the port in coming back. Thus the advantage of muzzle-pivoting, viz., the reduction of the size of port-holes, is to a large extent realised, without the necessity of lifting or lowering the gun itself.

Ships.—At the recent meetings at the Institution of Naval Architects, several very important papers were read relating to the form, size, and construction of ships. An examination of these in detail would occupy more space than we can now give to the subject, and we shall therefore do little more than name the several principal features of these papers. The prominent position which the question of the proper loading of mercantile vessels has lately assumed, has induced Mr. Benjamin Martell, Chief Surveyor of Lloyd's Registry of British and Foreign Shipping, to investigate the question as to what constitutes a fair freeboard for sea-going vessels, and he has accordingly prepared a scheme of freeboard for the various types of vessels in existence. A set of tables has now been published which determine, not a hard and fast load-line, which would be impracticable, but a fair line of reference for ordinary trades for the various types of sea-going sailing vessels and steamers of the first class. The principle governing this load-line is that of allowing a certain proportion of the total volume of the vessel above the water, in relation to her size and extreme length, and the mode adopted for cutting off this percentage of spare buoyancy is by multiplying the registered tonnage under deck by 100, and dividing this by the product of the length, breadth, and depth of the vessel. The quotient obtained affords a fair approximation to their relative fineness, from which the proper freeboard may be readily traced on the tables.

Mr. W. John's paper on the "Strength of Iron Ships" produces some facts which are sufficient to cause serious alarm, and ought, as he suggested, to secure a very careful consideration of the subject. He remarked, with regard to the constant tendency to increase the size of vessels, that, although it may not astonish anyone to hear that vessels over 300 feet in length are not as a rule strong enough to bear being pivoted on a rock or causeway amidships, it will probably surprise some to learn that they are liable to a strain of 8 tons per square inch afloat. "This," he states, "with the present state of the iron manufacture, gives a factor of safety of not more than 2½, which would scarcely be considered satisfactory by engineers for a land structure."

This paper was followed by one by Mr. W. Froude, F.R.S., Vice-President, on the "Useful Displacement as Limited by Weight of Structure and of Propulsive Power," in which it was remarked that the existing tendency towards extreme length, as compared with midship section, was only justified where extreme speed was required,—speed very much greater than that which sea-going merchant ships in fact realise. He drew a conclusion from prior arguments that the total sectional areas of the deck, the bottom, and the sides of a ship must be proportioned to the stress; and, as the structural weight may be taken as proportioned to their sectional areas multiplied by the ship's length, it must be regarded as proportional directly to the fourth power of the length, directly to the breadth, and inversely to the depth. From this follows the remarkable result that, alike whether we enlarge a ship by increasing her three dimensions throughout in the same given ratio, so as to enlarge her total displacement in the cube of that ratio, or whether we enlarge her by increasing her length alone, the increased structural weight will be as the fourth power of the enlargement of dimensions. It is obvious that in whatever degree the total dead weight of a ship's hull depends on her requirement of structural strength, this conclusion tells most unfavourably on the useful displacement of a ship enlarged simply by elongation, as compared with one enlarged in all her dimensions alike.

Mr. Nathaniel Barnaby, Vice-President, in a paper "On some Recent Designs for Ships of War for the British Navy, Armoured and Unarmoured," entered into particulars of size, form, and constructive details which could not well be given in a condensed form.

Some very interesting experiments for the determination of the resistance of a full-sized ship, at various speeds, by trials with H.M.S. *Greyhound*, were recently instituted by the Admiralty. The conclusion of these experiments was, that a comparison between the indicated horse-power of the *Greyhound*, when on her steam trials, and resistance of the ship, as determined by the dynamometer, showed that, making allowance for the slip of the screw, which is a legitimate expenditure of power, only about 45 per cent of the power exerted by the steam is usefully employed in propelling the ship, and that no less than 55 per cent is wasted in friction of engines and screw, and in the detrimental reaction of the propeller on the stream-lines of the water closing in around the stern of the vessel.

Railways.—The numerous railway accidents which have taken place of late have necessarily directed the attention of engineers and others interested in the working of railways to the question as to how accidents may be avoided, or, at least, lessened. This subject has been taken up by Captain Tyler, who recently read a paper before the Society of Arts on the "Working of Railways," and on simplicity as the essential element of safety and efficiency in the working of railways. From this paper we learn that the various classes of collision, and the accidents at facing-points, may together be roughly stated to comprise from two-thirds to three-fourths of the more serious casualties to railway trains. Railway working, which was at first easily conducted, is becoming a science with its separate branches, and deserves, therefore, careful study and investigation. Questions as to the arrangement and working of points and signals, and as to preserving intervals of time and space between trains and their accessories, enter more or less into the causes of the majority of railway accidents.

With regard to signals, by the application of locking and other apparatus it is possible to prevent nearly all those accidents which occur in consequence of any mistake of the signalman. Conflict between signals, and conflict between points and signals, may alike be avoided, and a good combination of locking, bar and bolt, may be made to ensure that the facing-points are completely over before the proper signal is lowered, and may also prevent them from being moved during the passage of a train. As regards signalmen, the selection and regular training of fit men for the performance of such duties as they have to perform; the employment of responsible inspectors for constant supervision, and the preservation of rigid discipline; the command of a sufficient number of relieving men to take Sunday duty and to replace signalmen absent from sickness or otherwise, and the maintenance in high condition of the whole of the apparatus, are matters of obvious importance; but experience has shown that it is by no means unnecessary to refer to them. By attention to these considerations, the dangers of facing-points are for the most part obviated, and engines and trains may be turned in and out, and across one another, with marvellous rapidity and facility, and in a way that would be otherwise impossible.

The next branch of the subject is that which refers to the preservation of intervals between trains; and this is best done by what is known as the block system. There are many descriptions of instruments for working the block system, and various rules and regulations applicable to it on different lines of railway. The main principle involved is, simply, by the division of a line into block sections, and by allowing no engine or train to enter a block section until the previous engine has quitted it, to preserve an absolute interval of space between engines and trains.

To sum up the whole case, it is necessary, in railway working, to deal with men and mechanism. Men are fallible, and mechanism may fail. The complications of railway construction and traffic have increased enormously, and are still increasing. At some points, the lines, the sidings, and the crossings are so numerous, and the traffic is so constant, that the employment of the best means and appliances is unavoidable. In other localities, of severe gradients or obstructed view, or when greater danger is otherwise incurred, similar means and appliances are also indispensable. These points and localities become more and more numerous, and ample experience has now been obtained as to the most efficient modes of working. The result of that experience has plainly demonstrated that mistakes and accidents may best be avoided, and efficiency of working may best be attained—(1) By judicious selection and careful training of the men employed, and especially, in a safety point of view, of engine-drivers and signalmen; (2) by providing those men with reasonable and necessary apparatus and accommodation for the proper performance of their duties; (3) by maintaining good discipline amongst them, which is only feasible when proper means and accommodation are provided, when proper modes of working are adopted, and when it is possible for them to carry out in practice the rules and regulations furnished for their guidance.

Directly bearing upon this subject, also, were two papers read before the Institution of Civil Engineers, the one, "Safety of Permanent Way," by C. P. Sandberg, and the other on "Railway Fixed Signals," by R. C. Rapier. We can now only briefly refer to these two papers. In the former one, the principal object the author had in view was to draw attention to the weakening of rails caused by punching or notching. In the latter, attention was chiefly given to the interlocking and block system, and a tabular statement exhibited showed that, by introducing this system on fourteen of the principal railways, by an expenditure of ½ per cent on the whole cost of the railways, their carrying power might be so increased that three times as many trains could be run on the block system as without it, and with greater safety.

Rock-Drilling.—With the ever-continuing increase in the progress of mining industries, the question of rock-drilling is gradually attaining an importance second to few others connected with the leading industries of the world. A paper on the subject of "Rock-Drilling Plant in its most Recent Modifications," was recently read before the Institution of Mechanical Engineers by Mr. T. B. Jordan, the principal object of which was to direct attention to the Darlington rock-drill, in which most of the defects of other drills were avoided. In this drill all the numerous small parts are omitted, and a machine has been produced that will make from 100 to 1000 blows per minute under a pressure of from 40 to 50 lbs. per inch. Only two parts are used to produce the percussive action of the machine—one fixed, and the other moving. The cylinder and cover may be considered as the fixed part, and the piston and rod—which are forged solid—as the moving part; and these are all that are required to produce the reciprocating action of the machine. The rotation of the tool is obtained by a rifled bar, which is fitted with a ratchet-wheel recessed into the cover of the cylinder. There is no automatic action for advancing the drill to follow up the work, the reason assigned for its absence being that experience has shown that the advantage gained by an automatic arrangement was by no means an equivalent for the extra trouble and expense they entailed.

A new rock-drill, which has for some time past been worked successfully in the United States, has recently been introduced into this country. It is the invention of Mr. Ingersoll, and the main points which constitute its novelty are the giving a rotary motion to a piston—either steam- or air-moved—and conveying that motion to the drill by means of a spiral rod connected to the piston. This rod has an adjustment, so that, when desired, the piston may work direct in one direction and be made to rotate in another. There is also an arrangement of tappets, by which the piston is forced slightly back just before the drill strikes the rock. A cushion is thus formed, which prevents the piston striking the end of the cylinder, and the shock of impact is received only by the drill-piece, and is not communicated to the other parts of the apparatus. The feed-motion of the drill is also governed by a tappet, which is struck by the piston in its forward stroke, and as the drill progresses into the rock.

GEOLOGY.

Physical Geology.—Mr. J. F. Campbell, in a paper on "Polar Glaciation," read before the Geological Society, described his observations made during thirty-three years, and especially those of last summer, when he travelled from England past the North Cape to Archangel, and thence by land to the

Caucasus, Crimea, Greece, and the South of Europe. In advancing southwards through Russia a range of low drift hills occurs about 60° N. lat., which may perhaps form part of a circular terminal moraine left by a retreating polar ice-cap; large grooved and polished stones of northern origin reach 55° N. lat. at Nijni Novgorod, but further east and south no such stones could be seen. The highest drift beds along the whole course of the Volga seem to have been arranged by water moving southwards. In America northern boulders are lost about 39°, in Germany about 55°, and in Eastern Russia about 56° N. lat., where the trains end, and fine gravel and sand cover the solid rocks. Ice-action, in the form either of glaciers or of icebergs, is necessary to account for the transport of large stones over the plains, and the action of moving water to account for drift carried further south. There are no indications of a continuous solid ice-cap following southward over plains in Europe and America to, or nearly to, the Equator; but a great deal was to be found on shore to prove ancient ocean circulation of equatorial and polar currents, like those which now move in the Atlantic, and much to prove the former existence of very large local ice-systems in places where no glaciers now exist.

Prof. Ramsay, in discussing the physical history of the Rhine Valley, stated his opinion that, during portions of the Miocene epoch, the drainage through the great valley between the Schwarzwald and the Vosges ran from the Devonian hills north of Mainz into the area now occupied by the miocene rocks of Switzerland. Then, after the physical disturbances which closed the Miocene epoch in these regions, the direction of the drainage was reversed, so that, after passing through the hill country between the Lake of Constance and Basle, the river flowed along an elevated plain formed of miocene deposits, the remains of which still exist at the sides of the valley between Basle and Mainz. At the same time the Rhine flowed in a minor valley through the upland country formed of Devonian rocks, which now constitute the Taunus, the Hundsruck, and the highland lying towards Bonn, and by the ordinary erosive action of the great river the gorge was gradually formed and deepened to its present level. In proportion as the gorge deepened, the marly flat miocene strata of the area between Mainz and Basle were also in great part worn away, leaving the existing plain, which presents a deceptive appearance of having once been occupied by a great lake.

Palæontology.—A new genus of corals has been founded by Dr. Nicholson, under the name of *Duncanella*, in compliment to Prof. Duncan, of King's College. The specimens of this coral have been found in the Lower Silurian rocks of Indiana.

Mr. L. C. Miall, Curator of the Museum of the Leeds Philosophical Society, has published an excellent guide to the Fossil Collection in the Museum, which is in itself a capital elementary introduction to Palæontological Science: the principal groups of fossils, both plants and animals, are described, and their modes of preservation are pointed out, whilst numerous references are given to works which would prove useful to the student.

Mr. Seeley has recently described a new genus of Plesiosaurians from the Oxford Clay, which he has named *Muræonsaurus*.

A new family of Palæozoic Brachiopoda has been established by Mr. Davidson and Dr. King, which they call the *Trimerellidæ*. As far as is at present known they are confined to the Cambro-Silurian and Silurian systems.

Sub-Wealden Exploration.—A total depth of 671 feet has now been reached, and the boring is still in the Kimeridge Clay. Mr. Topley, who has examined the specimens below the depth of 376 feet, reports that slight indications of petroleum have been noticed all through the clay. He has been able to record no less than twenty forms of Mollusca (the species cannot always be identified) and some fish-remains. *Ammonites biplex*, *Cardium*, *Modiola pectinata*, and *Lingula ovalis* are the most abundant fossils in the Kimeridge Clay. It is not quite certain at what exact depth in the boring the Kimeridge Clay began, but it was probably about 290 feet from the surface, so that about 380 feet of it have been penetrated. Its total thickness at Netherfield (near

Battle) was estimated at 400 feet, so that no doubt the bottom will soon be reached.

The discovery of beds of gypsum between the depths of 100 and 180 feet, in the Purbeck Beds, and which would probably never have been known but for this scientific enterprise, have been already sought for and found at Archer's Wood, on the estate of the Earl of Ashburnham. As Mr. Willett observes, it is a matter of congratulation that by this discovery there has been developed for the county a new industry, which promises to be highly remunerative to all parties.

Geological Society of London.—This Society has just commenced the removal of its Library and Collections from Somerset House to the new apartments prepared at Burlington House. The superior accommodation, which was more especially wanted to display the large collections of rocks and fossils, will no doubt be appreciated by the Members.

The late Professor Phillips.—The scientific world at large, and geologists particularly, have sustained a great loss in the death of Professor Phillips. Few men have possessed so wide a range of knowledge, and no one has done more to further the advance of Geology, by special work in all its departments, than John Phillips. He was born in 1800, and, being early left an orphan, was adopted by his uncle, William Smith, the Father of English Geology. From his sixteenth year he accompanied Smith in his various geological journeys across England, and was thus early trained to accurate observation in the field by his uncle, whose early teachings directed the whole course of his life. In 1825 he was appointed Keeper to the Museum of the Yorkshire Philosophical Society, a post which he held until 1840, when he was appointed to the Geological Survey under De la Beche, and not only did much detailed work in the field, but described the Palæozoic fossils collected in West Somerset, Devon, and Cornwall. In 1834 Mr. Phillips was elected to the Chair of Geology in King's College, London; in 1844 he was appointed Professor of Geology in the University of Dublin; and in 1853 he was called to the duties of Reader in Geology in the University of Oxford. In 1859 he was elected President of the Geological Society of London, and in 1864 President of the British Association, of which latter body he was one of the founders. The writings of Professor Phillips were very numerous. At the time of his death he was preparing a new edition of his "Geology of Yorkshire." He died on the 24th of April, having met with a severe accident on the previous day, falling headlong down a flight of stone stairs.

PHYSICS.

MICROSCOPY.—Mr. F. H. Wenham has described* a more accurate mode of measuring the angular aperture of microscopical objectives than that hitherto practised. The angle of aperture of an object-glass is taken from the focal point through which the rays must pass for all degrees. Those entering at other angles within the plane of focus will give a false indication, from diffused light forming no image. Mr. Wenham employs a movable slit of thin platinum-foil so mounted as to be secure from damage from accidental contact with the object-glass, or otherwise. This instrument is placed upon the stage of the microscope, with the body horizontal, and set on a wooden turntable about 10 inches in diameter, having its edge divided into degrees. The object-glass to be measured is focussed on the glass surface, and the slit adjusted so that its two edges just appear in the field of view, and by the rotation of the turntable the degrees of aperture are read off. The microscope should have a thin stage, so that the rays may not be cut off at extreme angles. Measurements taken with these precautions come out much lower than those by the ordinary mode, as the image-forming rays alone enter into the objective. Mr. Wenham considers the large front glasses of many objectives not only useless but injurious, and the performance of such glasses is much improved by turning away the front, so as to only leave the actual working portion to receive the pencil from the object. Many fine glasses perform indifferently under certain conditions of illumination from the above cause, but, by placing a cap with a suitable aperture to exclude useless light, the definition is rendered perfect. The celebrated American $\frac{1}{8}$th objective, marked as having an angular aperture of 180°, is a remarkable instance of erroneous measurement obtained by receiving false light. The following are the data:—Diameter of front lens, 0·043 of an inch; working distance, 0·013 of an inch. From these measurements, 118° is the utmost that can be obtained, supposing all the light entering takes part in the formation of the image; this glass, measured in the ordinary way, admitted light up to 180°.

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* Monthly Microscopical Journal, vol. xi., p. 198.

A series of more than eighty slides for the magic-lantern, illustrating geology and palæontology, have been published by Mr. James How, of Foster Lane; they are uniform in size with Dr. Maddox's micro-photographs, and are photographed from the best drawings and engravings of various fossils, sections of strata, and sedimentary formations. New photographs are in preparation; the series will prove of great value in illustrating lectures on geological subjects. It is to be regretted that the colour and condition of most geological specimens is such as to prevent good photographs suitable for lantern magnification being taken directly from them.

We have to record the death of Mr. Henry Deane, F.L.S., F.M.S., F.R.M.S., which took place suddenly at Dover on April 11. Mr. Deane joined the Royal Microscopical Society (then the Microscopical Society of London) at its commencement in 1840, and was associated with Messrs. Bowerbank, Bell, Mantell, Quekett, and other pioneers of microscopical science. In 1845 he discovered the existence of *Xanthidia* and *Polythalamia* in the grey chalk of Folkestone, also the now well-known *Arachnoidiscus Japonica* on the sea-weed used by the Chinese for preparing soup. He was also the first to introduce gelatinous mounting media, Deane's gelatine being still employed by microscopists, and considered a most reliable material. It is, however, with the foundation and progress of the Pharmaceutical Society that Mr. Deane's name will be longest remembered. He became one of the Board of Examiners in 1844, and introduced many improvements of a highly practical nature into the examinations, practical dispensing being one of the most notable. He was elected Member of Council in 1851, Vice-President shortly afterwards, and President in 1853 and 1854. Mr. Deane was Chairman of the Committee appointed to assist the College of Physicians in compiling a new Pharmacopœia, and also President of the first British Pharmaceutical Conference. Very few papers were written by Mr. Deane, although his work, both with the microscope and in chemical and pharmaceutical science, was considerable. Attention may, however, however, be called to "Displacement as a Method of Preparing Tinctures, &c.;"* "Experiments on Senna;"† also some on opium preparations and extract of meat, in conjunction with Mr. H. B. Brady.

The subject of cutting sections for the microscope has been very fully discussed at the Quekett Microscopical Club. A large collection of machines were exhibited and described by Mr. E. T. Newton. The points considered most needful to a perfect section-cutter were a true guide-plate, and a very accurate, finely-divided, and tight-fitting screw; a large tube is to be preferred to one of small bore, and the machine should be firmly clamped to the table or bench. Opinions were divided as to the form of the cutting instrument, some being in favour of a knife with a blade broad at the heel and narrow at the point, and others preferring a straight edge; all, however, agreeing that the blade must be so strong that it will not bend under the necessary pressure, as in that case it would dip down and cut an uneven section, besides being liable to come in contact with the edges of the tube and consequently be blunted. It is hardly necessary to mention that success entirely depends upon the knife being extremely sharp. Some experienced operators consider a sharp knife the chief requisite, dispensing with the aid of a machine, and trusting entirely to steadiness of hand. Dr. Hoggan has contrived a machine differing entirely from those on the tube principle almost universally employed. The substance to be cut is attached to a plate worked by a screw somewhat after the manner of the well-known slide-rest of the lathe; the contrivance, which is adapted for cutting sections of either hard or soft substances, has means of keeping the saw or knife rigidly in position while at work. Among the substances used for imbedding tissues to be cut, carrot and elder-pith seemed to offer especial advantages. The process of freezing soft tissues gives good results, and is convenient, because the tedious process of hardening with alcohol or chromic acid is dispensed with; gum-water should be used for imbedding, as water when frozen blunts the knife at the first cut, owing to its becoming crystallised.

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* Pharm. Journ., vol. i., p. 61.

† *Ibid.*, vol. iv., p. 61.

HEAT.—M. Berthelot, writing on refrigerating mixtures, says the thermal effect produced when ice is mixed with bihydrated crystallised sulphuric acid is the sum of three effects, viz., the fusion of the acid and that of the ice, which absorb heat, and the combination of the two liquids, which liberates heat. The numbers obtained in practice are under those calculated from theory, owing to loss through radiation. The author shows from theory that no method of cooling is comparable to vaporisation, and he thinks that much higher temperatures may yet be had by means of it.

In prosecuting experiments to ascertain the expansion of various substances by heat, the following experiment was tried:—The bulb of a thermometer was suddenly plunged into melted lead. The mercury instantly darted down far below zero. The action was so quick that the point could not be ascertained. This was caused by the sudden expansion of the bulb by heat before it reached the mercury by conduction; this then began to rise very rapidly, and before it had arrived at the top of the tube the bulb was withdrawn. The experiment requires adroitness, for, as we all know, the instant that the mercury touches the top, the bulb will burst. This must be greased before immersion in the fused lead, otherwise a film of the metal will adhere and retain sufficient heat to carry the mercury to the top with a consequent fracture. A thermometer treated in this rough manner afterwards showed an index error of six degrees, the mercury having risen to that extent; but after a few days the equilibrium was partly restored, and the error remained permanently at three degrees.

Dr. H. Beins in considering the question how to transform heat into mechanical power more advantageously than it is done in our common steam and other engines, found that when natrium-bicarbonate (or the corresponding salt of kalium) in a dry pulverised state or in a watery solution is heated in a closed space, a part of the carbonic acid is given off and condensed in a not heated portion of that space, so that at a temperature of 300° to 400° C. liquid carbonic acid can be distilled out of those salts with a tension of from 50 to 60 atmospheres. The author has experimentally found that a carboleum-engine is easily constructed. Taps and joints can be made to answer perfectly. A year ago he filled a tube of hammered copper with carbonic acid of 50 atm., and not the least loss is as yet observed. Wrought metals are therefore not permeable for gases of that tension. Perhaps the phenomena of porosity, belonging to the common air-pump experiments, are partly caused by surface-condensation. For the great industry, the carboleum-engine can in almost every case substitute the steam-engine. For the small industry, specially for engines working with intermissions and during brief spaces of time, the property of carboleum of being always ready for work is of much importance; for instance, for printing-presses, fire-engines, street-locomotives, &c. By this same property, and since the mechanical equivalent of electricity is very small, a carboleum-engine is a fit and cheap source of electrical light. This method of compression furnishes easily the required tension for the conveyance of letters in tubes, and the modern break apparatus for railways. Perhaps the property of carboleum of possessing a power of projection a hundred times cheaper than gunpowder can be made use of. The fact that a carboleum-engine with sufficient store of carboleum is independent of our atmosphere, makes it possible to construct a vessel, provided with means to sink to any depth of the sea, to rise and sink at will, to cruise about under water, and to maintain the life of the crew during that operation, to develop light, &c. The importance of this for scientific discoveries and industrial purposes is evident. For the purposes of war, also, must such a small and comparatively cheap submarine vessel place a peculiar, nay a decisive, weight in the scale in the question of our modern ironclads. Freezing machines working by evaporation of carboleum produce ice at a much less cost than any existing freezing apparatus. Regarding this general usefulness of carbonic acid, it is important to call attention to the fact that an inexhaustible store of carboleum is at our disposition in common chalk, for this mineral contains carbonic acid to the amount of half its weight; it can therefore produce twice its volume of carboleum.

ELECTRICITY.—M. Clamond has been improving his thermo-electric pile. He found in it a considerable increase of resistance, and this was due to two causes—(1) Oxidation of the contracts of the polar plates with the crystallised bar under the influence of heat; and (2) splitting of the bar and separation of its different parts in planes perpendicular to its length. In making his couple he uses an alloy of zinc and antimony, and plates of iron as armatures. The bars are collected in crowns of ten bars each, superposed and separated by washers of amianthus, and coupled for tension. The whole forms a cylinder, the interior of which is luted with amianthus, and heated by means of a pipe of refractory earth pierced with holes. The gas mixed with air burns in the annular space between the tube and the bars. The entire surface of the crowns of the pile is 35 square decimetres. The consumption of gas is controlled by M. Girond's regulator. Thus arranged, the pile will work whole months without requiring attention, giving a current absolutely constant. A model exhibited consumed 170 litres, that is, about 5 centimes of gas in the hour, and deposited 20 grms. of copper, which makes the expense of gas per kilogrm. of copper deposited 2 francs 50 cents. M. Clamond has made models of various size; the quantity of electricity increases proportionally to the size of the pieces.

The lever of an electric automatic whistle for locomotives is wrought by an electro-magnet. On passage of a current in a certain direction the magnet lets go the lever, and the whistle sounds. The apparatus is connected by insulating wires with a metallic brush projecting below the locomotive. At a short distance in front of the sight signal there is a metallic plate between the rails, which, when the signal is turned in the position for stoppage, is connected with a source of electricity. On passage of the brush over the plate the current flows and the whistle sounds. It continues to do so till adjusted again by the engine-driver. The Chemin de Fer du Nord have used the system, which is the invention of MM. Lartigue and Forest, eight months, and with satisfactory results.

The following safety electric cable against fires is proposed by MM. Joly and Barbier:—Two wires, insulated from each other by gutta-percha, are corded together into a cable, and are connected at one end with a battery and electric bell. When fire breaks out in any part of the building through which the cable passes the gutta-percha is freed and the wires come in contact, thus closing the circuit and ringing the bell. The condition of the apparatus is tested by means of a peg commutator at the other end of the cable.

TECHNOLOGY.

A new use of glycerin is to prevent the formation of incrustation in steam-boilers. M. Asselin, of Paris, recommends the addition of glycerin in the proportion of 1 kilo. for every 5000 to 8000 kilos. of fuel consumed, on account of its power of increasing the solubility of sulphate of lime, and causing the undissolved portion to be precipitated in a granular form, so as not to adhere to the metal.

As a system of continuous alarum signals to prevent collisions, on railways or at sea, in foggy weather, M. de Mat proposes to compress air in a cylindrical reservoir, from which a tubulure conveys it to three organ pipes (giving *do*, *mi*, *sol*), which can be sounded separately or together. In fog the *do* is sounded, and whenever an engine-driver hears it in an advancing train he sounds his *mi*, the other driver then sounds his *mi* if he is on the right line, then both sound *sol*.

LIST OF PUBLICATIONS RECEIVED FOR REVIEW.

A Manual of Botany, Anatomical and Physiological, for the Use of Students. By Robert Brown, M.A., Ph.D. *Wm. Blackwood and Sons.*

Botanical Tables for the Use of Students. Compiled by Edward B. Aveling, B.Sc. *Hamilton, Adams, and Co.*

Divine Revelation or Pseudo-Science? By R. G. Suckling Browne, B.D. *Longmans, Green, and Co.*

Algebra Identified with Geometry. By A. J. Ellis, F.R.S. *C. F. Hodgson and Sons.*

Theory of Arches. By Prof. W. Allan. *New York: D. Van Nostrand.*

A Treatise on an Improved Method for Overcoming Steep Gradients on Railways. By Henry Handyside. *E. and F. N. Spon.*

Qualitative Chemical Analysis and Laboratory Practice. By T. E. Thorpe, Ph.D., F.R.S.E., and M. M. Pattison Muir, F.R.S.E. *Longmans, Green, and Co.*

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Physiology. By F. Le Gros Clark, F.R.S. *Society for Promoting Christian Knowledge.*

Mineralogy. By Frank Rutley, F.G.S. *London: Thomas Murby.*

The Correlation of Physical Forces. Sixth Edition. By the Hon. Sir W. R. Grove, M.A., F.R.S. *Longmans, Green, and Co.*

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Harvey and His Times. The Harveian Oration for 1874. By Charles West, M.D. *Longmans, Green, and Co.*

Elements of Metallurgy. By J. Arthur Phillips, M. Inst. C.E., F.G.S., &c. *Charles Griffin and Co.*

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Arithmetic in Theory and Practice. By J. Brook-Smith, M.A., LL.B. 2nd edition. *Macmillan and Co.*

The Sanitary Condition of Oxfordshire. By Gilbert W. Child. *Longmans, Green, and Co.*

Principles of Mechanics. By T. M. Goodeve, M.A. *Longmans, Green, and Co.*